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MISCELLANEOUS PAPER S-71-29

EVALUATION OF HARVEY ALUMINUM 1- BY 12-FT EXTRUDED LIGHT-DUTY LANDING MAT WITH OVERLAP/UNDERLAP END CONNECTORS

by

H. L. Green, C. T. McCormick



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December 1971

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Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Engineer Waterways Experiment Station Vicksburg, Mississippi		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3. REPORT TITLE EVALUATION OF HARVEY ALUMINUM 1- BY 12-FT EXTRUDED ALUMINUM LIGHT-DUTY LANDING MAT WITH OVERLAP/UNDERLAP END CONNECTORS			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final report			
5. AUTHOR(S) (First name, middle initial, last name) Hugh L. Green Charles T. McCormick			
6. REPORT DATE December 1971		7a. TOTAL NO. OF PAGES 64	7b. NO. OF REFS 7
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S) Miscellaneous Paper S-71-29	
b. PROJECT NO. 1G664717DH01 Task 10			
c.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.			
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY U. S. Army Materiel Command Washington, D. C.	
13. ABSTRACT <p>The investigation reported herein was conducted to evaluate an extruded aluminum alloy landing mat that was designed and fabricated by Harvey Aluminum Company, Inc., Torrance, Calif. The 1- by 12-ft mat is a one-piece hollow extrusion fabricated from 6063 aluminum alloy artificially aged to the T6 condition. The mat panels are interlocked along the sides by means of a hinge-type connector, the components of which are integral parts of the basic extrusion. End connectors, composed of extruded connectors welded to the basic panel and aluminum inserts using the electron beam (EB) welding method, consist of overlap and underlap sections that are secured by a locking bar after individual panels have been joined together. The investigation consisted of laboratory, traffic, and skid tests to obtain information for use in evaluating Harvey mat for potential use as a light-duty landing mat. Traffic tests were conducted with the mat placed on a prepared subgrade and trafficked with a rolling wheel load simulating actual aircraft operations. The tests were conducted using the C-130 aircraft loading, which consisted of a single-wheel load of 30,000 lb with a tire inflation pressure of 100 psi, on a subgrade with a rated CBR of 4.2. Results of this investigation revealed that the Harvey light-duty mat sustained 450 actual coverages of traffic on a subgrade with a rated CBR of 4.2, which is equivalent to 367 coverages on a 4-CBR subgrade. This falls short of the coverage criterion for light-duty mat, i.e. 1000 coverages on a 4-CBR subgrade. Failure of the panels occurred in the mat body with breakage in the top skins, bottom skins, and internal vertical members. No failures occurred at the end joints in the vicinity of the welds even though voids were present in the welds in some areas. The placement rate of the mat was 370 sq ft per man-hour. The average coefficients of friction obtained from skid tests on wet and dry surfaces were 0.62 and 0.73, respectively. The tire wear resulting from skidding on both the wet and dry surfaces was not considered significant. Laboratory tests conducted on the mat indicated that the 6063-T6 alloy exceeded the minimum physical requirements stipulated.</p>			

DD FORM 1473
1 NOV 65

REPLACES DD FORM 1473, 1 JAN 64, WHICH IS
OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	Harvey Aluminum Co., Inc. Laboratory tests Landing mats Skid tests Traffic tests						



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ARMY-MRC VICKSBURG, MISS

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FOREWORD

This report was prepared as a part of the work authorized by the Ground Mobility Division, Directorate of Research, Development, and Engineering, U. S. Army Materiel Command (AMC), under the title "Combat Engineer Equipment," DA Project No. 1G664717DH01 - Task 10, "Landing Mat Development."

The engineer design tests pertinent to this investigation were performed at the U. S. Army Engineer Waterways Experiment Station (WES) during September and October 1969 under the general supervision of Mr. J. P. Sale, Chief, Soils Division. Engineers of the Expedient Surfaces Branch who were actively engaged in the planning, testing, analyzing, and reporting phases of this investigation under the supervision of Messrs. W. L. McInnis and H. L. Green were Messrs. D. W. White, Jr., and C. T. McCormick. The Flexible Pavement Branch was responsible for constructing and trafficking the test section and for performing the necessary soil tests under the supervision of Messrs. R. G. Ahlvin and C. D. Burns. This report was prepared by Messrs. Green and McCormick.

Directors of the WES during the conduct of this study and the preparation of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	2.54	centimeters
feet	0.3048	meters
square inches	6.4516	square centimeters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
pounds	0.45359237	kilograms
kips	453.59237	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
pounds per square foot	4.88243	kilograms per square meter
pounds per cubic foot	16.0185	kilograms per cubic meter
miles per hour	1.609344	kilometers per hour

SUMMARY

The investigation reported herein was conducted to evaluate an extruded aluminum alloy landing mat that was designed and fabricated by Harvey Aluminum Company, Inc., Torrance, Calif. The 1- by 12-ft mat is a one-piece hollow extrusion fabricated from 6063 aluminum alloy artificially aged to the T6 condition. The mat panels are interlocked along the sides by means of a hinge-type connector, the components of which are integral parts of the basic extrusion. End connectors, composed of extruded connectors welded to the basic panel and aluminum inserts using the electron beam welding method, consist of overlap and underlap sections that are secured by a locking bar after individual panels have been joined together. The investigation consisted of laboratory, traffic, and skid tests to obtain information for use in evaluating Harvey mat for potential use as a light-duty landing mat. The test data reported herein were evaluated against the criteria for light-duty mat as established in the revised Qualitative Materiel Requirement presented as Appendix A.

Traffic tests were conducted with the mat placed on a prepared subgrade and trafficked with a rolling wheel load simulating actual aircraft operations. The tests were conducted using the C-130 aircraft loading, which consisted of a single-wheel load of 30,000 lb with a tire inflation pressure of 100 psi, on a subgrade with a rated CBR of 4.2. Results of this investigation revealed that the Harvey light-duty mat sustained 450 actual coverages of traffic on a subgrade with a rated CBR of 4.2, which is equivalent to 367 coverages on a 4-CBR subgrade. This falls short of the coverage criterion for light-duty mat, i.e. 1000 coverages on a 4-CBR subgrade. Failure of the panels occurred in the mat body with breakage in the top skins, bottom skins, and internal vertical members. No failures occurred at the end joints in the vicinity of the welds even though voids were present in the welds in some areas.

The placement rate of the mat was 370 sq ft per man-hour. The average coefficients of friction obtained from skid tests on wet and dry surfaces were 0.62 and 0.73, respectively. The tire wear resulting from skidding on both the wet and dry surfaces was not considered significant.

Laboratory tests conducted on the mat indicated that the 6063-T6 alloy exceeded the minimum physical requirements stipulated.

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LANDING MAT WITH OVERLAP/UNDERLAP END CONNECTORS

PART I: INTRODUCTION

Background

1. The investigation reported herein was an engineer design test (EDT) in the U. S. Army Materiel Command's (AMC) RDT&E program for the development of landing mats satisfactory for use as expedient surfacing materials for forward-area airfields. As a part of this program, the U. S. Army Engineer Waterways Experiment Station (WES) has been assigned the responsibility for landing mat development and currently is developing three classes of landing mat: light-, medium-, and heavy-duty mats.

2. The steps that ultimately led to the design of the Harvey light-duty mat began initially with the development of extruded T8 magnesium mat and the similarly designed extruded T11 aluminum mat, which represented the potential for a tremendous advancement in the design of landing mats. Through the extrusion process, metal can be placed where it will do the most good, resulting in a stronger mat of reduced weight. Field tests conducted at WES¹ indicated that the extruded T11 mat was superior to previously tested mats and prompted a limited field test of the modified T11 aluminum mat by the Air Force at England AFB, Alexandria, La., from December 1963 to July 1964. Results of these tests^{2,3} prompted the Air Force to formulate "Performance Requirements for Landing Mat," which was sent to AMC as an inclosure to a letter, subject: Development of Landing Mat, dated 8 October 1964. A Qualitative Materiel Requirement (QMR) for pre-fabricated airfield surfacings, dated 12 July 1966, was approved using the loadings that evolved from the Air Force requirements. This QMR was subsequently revised, and a new one was approved on 2 April 1968. The test data reported herein were evaluated against the criteria for light-duty mat as established in the revised QMR, which is presented as Appendix A.

Objectives

3. The general objectives of this investigation were to evaluate both the design and the performance of Harvey 1- by 12-ft light-duty landing mat and to determine its suitability for use as an expedient surfacing material for forward-area bases. The specific objectives of this investigation were to determine:

- a. The service life (1000 coverages minimum required) of the mat when placed on a subgrade having a CBR of 4.0 and trafficked with a 30,000-lb* single-wheel load with tires inflated to 100 psi to produce a contact area of approximately 328 sq in.
- b. The coefficients of friction of the mat with both wet and dry surfaces.
- c. The average placement rate of the mat.
- d. The mechanical and physical properties of the mat.

Scope

4. This report describes and gives results of accelerated traffic tests and laboratory tests conducted to evaluate the Harvey mat. The desired data were obtained by the EDT as follows:

- a. Traffic tests were conducted on a specially constructed test section to study subgrade behavior and to observe the performance of the mat under a rolling wheel load.
- b. The force required to skid a load cart over the mat both when dry and when wet was recorded, and the coefficient of friction was determined.
- c. During the assembly of the test section, mat placement time was recorded, and the placing rate was computed.
- d. Laboratory tests were conducted to evaluate the mechanical and physical properties of the mat.

Definitions of Pertinent Terms

5. For information and clarity, definitions of certain terms used in this report are given below:

* A table of factors for converting British units of measurement to metric units is presented on page ix.

Test section. A prepared area on which the landing mat is placed for test purposes.

Traffic lane. Area of the test section that is subjected to the rolling wheel load of the load cart.

Subgrade. The portion of the test section constructed with soil processed under controlled conditions to provide the desired bearing capacity and upon which the landing mat is placed.

CBR (California Bearing Ratio). A measure of the bearing capacity of the soil based upon its shearing resistance. CBR is calculated by dividing the unit load required to force a piston into the soil by the unit load required to force the same piston the same depth into a standard sample of crushed stone and multiplying by 100.

Run. A strip of landing mat equal to one panel width and extending transversely across the entire test section.

Coverage. One application of the test wheel of the load cart over every point in the traffic lane.

Load cart. A specially constructed cart used in WES engineering tests for simulating aircraft taxiing operations.

Test wheel. The wheel on the load cart that supports the main load.

Extrusions. Shapes produced by forcing cast billets, heated to a plastic condition, through a steel die opening of the desired cross section.

Deflection. Temporary bending of landing mat panels under the static load from the test wheel of the load cart.

Transverse dishing. Permanent deformation of a panel parallel to the direction of traffic.

Longitudinal dishing. Permanent deformation of a panel perpendicular to the direction of traffic.

Direction of traffic. The direction in which the load cart travels on the test section. The direction of traffic is representative of actual landing directions with respect to panel joints.

PART II: DESCRIPTION OF MAT

Fabrication Features

6. The 1- by 12-ft landing mat was designed and fabricated by Harvey Aluminum Company, Inc., Torrance, Calif., and was extruded from 6063 aluminum alloy artificially aged to the T6 condition, which involves heat treatment and oven cycling to produce a stable temper. In the past, extruded landing mat designs (XM18, XM20, truss web, etc.) have incorporated the use of 6061-T6 aluminum alloy. However, due to the incapability of the strongest die steels to withstand the extrusion forces generated by forcing the aluminum through the small openings of the die designed to form the skins and ribs of the light-duty mat, it was necessary to use 6063-T6 aluminum alloy instead. Mechanical properties of the extruded 6063-T6 and 6061-T6 aluminum alloys, as specified in the American Society for Testing and Materials (ASTM) Standards,⁴ (ASTM Designation: B221-69) are as follows:

	<u>6063-T6</u>	<u>6061-T6</u>
Tensile strength, psi		
Ultimate	30,000	38,000
Yield	25,000	35,000
Elongation, percent (2-in. gage length)	8.0	8.0

7. With aluminum mats, the metallic-inert-gas (MIG) welding process that had been used previously in welding end connectors to mat extrusions was unacceptable, since the attendant penetration of approximately 70 percent of the metal would destroy the relatively thin skins of the basic extrusion. Therefore, an electron beam (EB) welding process was used since it could be utilized to weld the thin skins of the panel extrusion to the end connector extrusion (provided inserts were used).

8. Fig. 1 shows a cross-section view of the multihollow extrusion, which had top skin thicknesses averaging 0.068 in. and bottom skin thicknesses averaging 0.040 in. Impact-extruded aluminum inserts were used inside the hollows at the ends of the panel extrusion to provide additional material and a uniform welding surface for the EB during welding. This was necessary since no additional welding flux or wire is used in the process

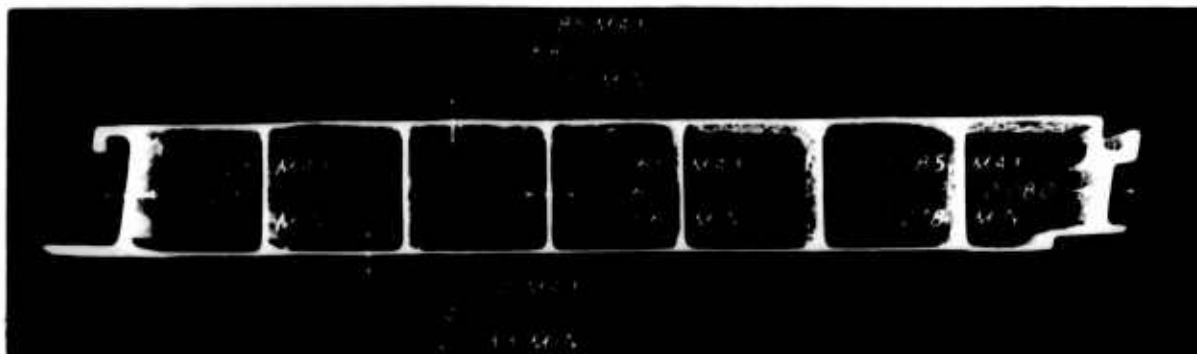


Fig. 1. Cross-section view of light-duty mat extrusion

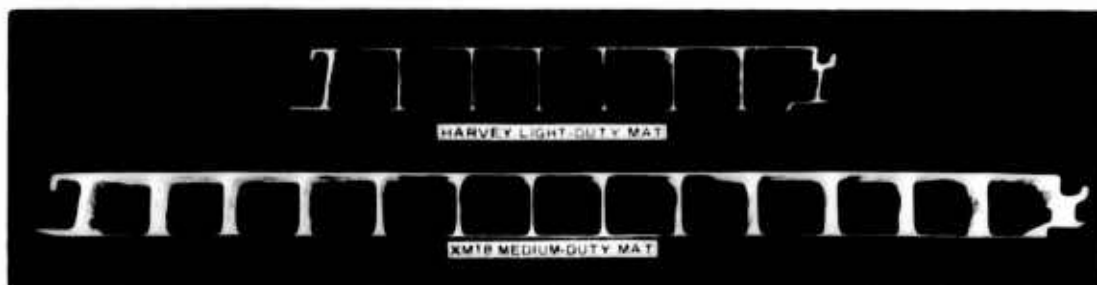


Fig. 2. Cross-section view of light- and medium-duty mat extrusions

because the basic materials being welded (skins, ribs, inserts, and connectors) are fused together. For comparison, a cross-section view of the XML8 medium-duty mat is shown with a cross-section of the Harvey light-duty mat in fig. 2. The Harvey mat weighed 3.09 lb per square foot of placing area, which slightly exceeds the maximum weight of 3.0 lb per square foot of placing area specified in the QMR.

9. Individual panels are interlocked along the sides by a hinge-type, male-female connector, the components of which are integral parts of the basic panel extrusion. End joints are secured by a locking bar after individual panels have been positioned. A view of a panel of the mat is shown in fig. 3.



Fig. 3. Full panel of 1- by 12-ft Harvey light-duty mat

Ancillary Items

10. The ancillary items designed for use with the Harvey mat in actual field installations included repair mats, starter connectors, closure panels, turn adapters, and ramp sections (fig. 4) and 45-deg transition panels (fig. 5). These items, shipped in a separate bundle, were not evaluated since the basic mat failed to perform satisfactorily.

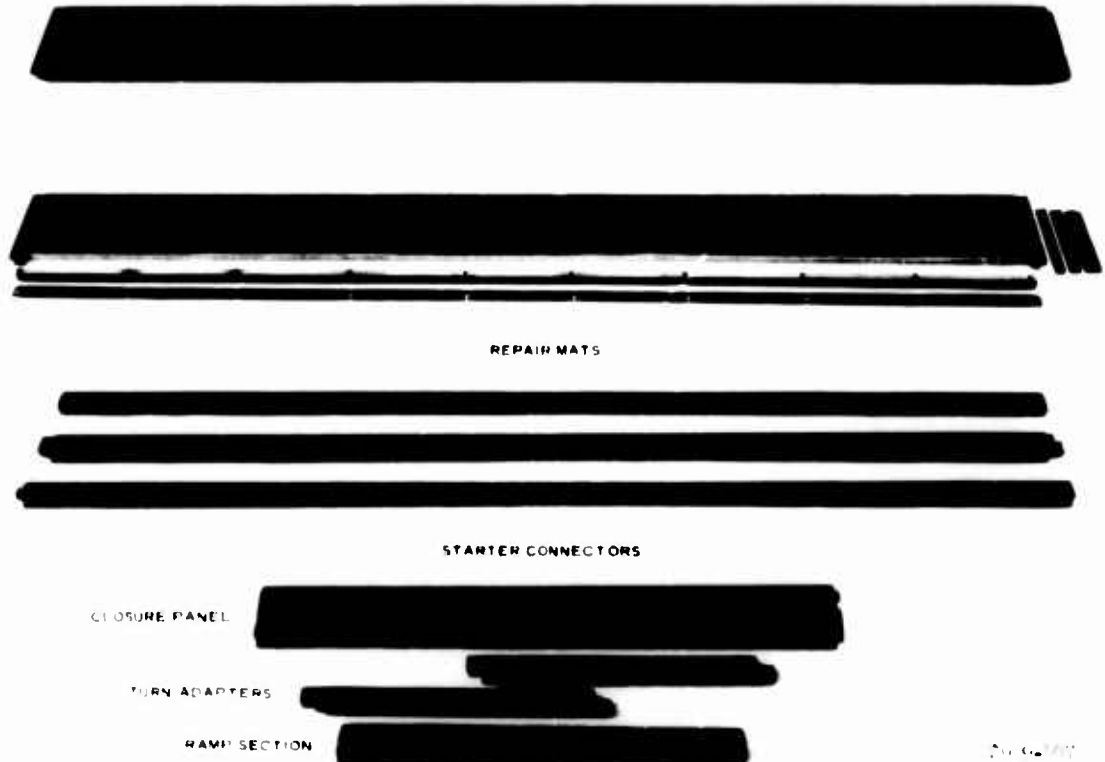


Fig. 4. Ancillary items designed for field use with light-duty aluminum mat

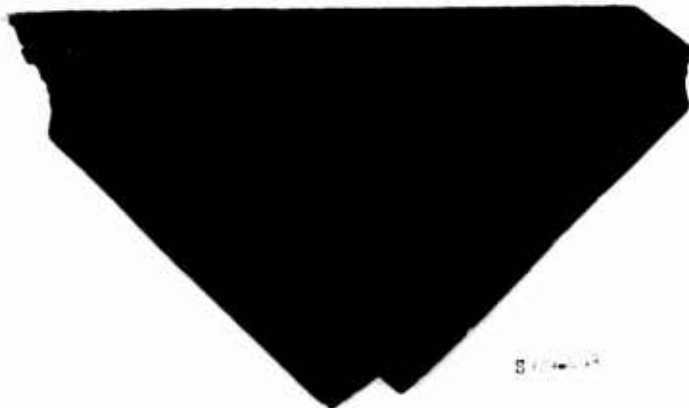


Fig. 5. Forty-five-deg transition panel

Physical Dimensions

11. The mats were shipped in bundles of both full and half panels. Each bundle weighed approximately 1700 lb. A typical bundle is shown in fig. 6. Individual panels and bundles were measured and weighed, and average dimensions and weights are as follows:

Panels*							
Overall Dimensions, in.			Placing Dimensions			Weight	
						Per Panel	Per Square Feet of Placing Area, lb
Width	Length	Depth	in.	in.	sq ft	lb	
12.87	145.00	1.50	12.00	144.00	12.00	37.06	3.09

* The half panels were approximately 1 by 6 ft and 1.5 in. thick, and the average weight per panel was 20.37 lb.

Bundles				
Length	Width	Height	Volume	Weight
ft	ft	ft	cu ft	lb
12.23	2.56	2.38	74.52	1700



Fig. 6. Bundle of Harvey aluminum landing mat as received from the manufacturer

Mat Inspection

12. Fig. 7 shows a close-up of the bottom of a panel with a typical EB weld. Inspection revealed that many of the mats had voids in the welds. An end-joint weld that contained welding voids is shown in fig. 8.

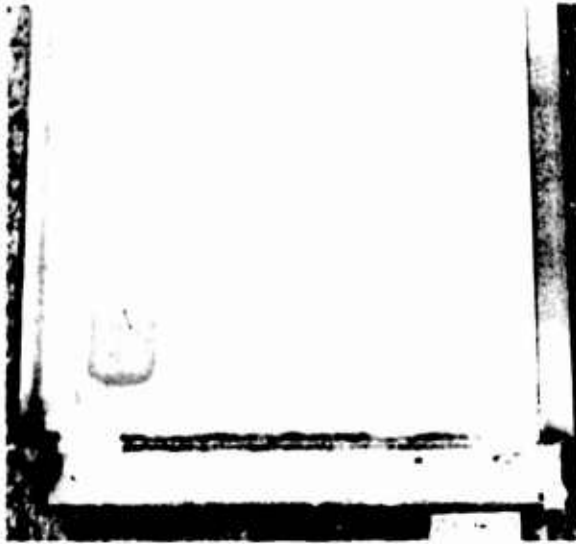
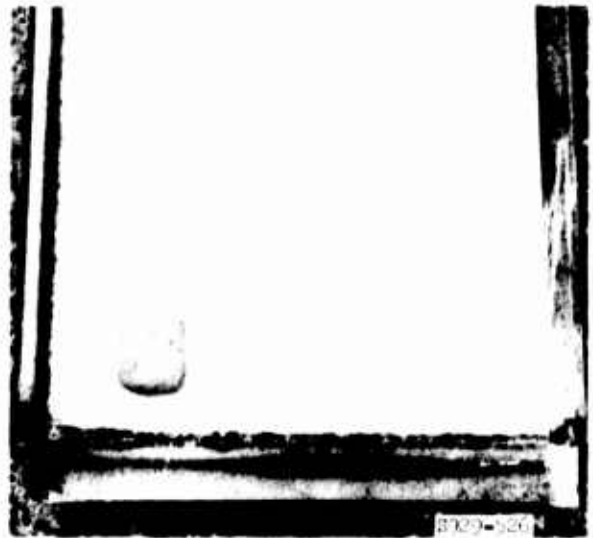


Fig. 7. Bottom view of mat panel showing end-joint weld

Fig. 8. Close-up of end joint showing defective weld with voids



PART III: TEST SECTION AND EQUIPMENT

Test Section

Location and description

13. The test section was constructed at the WES under a hangar-type structure to provide both protection from the elements and the conditions necessary for accurately controlled comparative traffic tests. The test section was 24 ft wide by 40 ft long with a 10.8-ft-wide traffic lane in the longitudinal center and a 30-ft-long approach area at each end. A general layout showing the panel numbering system is presented in plate 1. All panels were placed on the section with the longitudinal axis of the mat perpendicular to the center line of the test and approach sections.

Construction of subgrade

14. The test section was excavated to a depth of 24 in. below final grade, and a heavy clay material (CH) having an average liquid limit of 58 and an average plasticity index of 33 (see plate 2) was used to backfill the section. The clay was processed to ensure uniformity, hauled to the test section, and spread with a bulldozer to provide 6-in. lifts after compaction. Each lift was mixed in place with a pulvimixer and then compacted with 8 coverages of a self-propelled, seven-wheel, rubber-tired roller loaded to 41,000 lb and having a tire inflation pressure of 90 psi. The surface of each compacted lift was scarified and then sprinkled with water prior to placement of the next lift. Construction control data were obtained for each lift after compaction by means of in-place CBR, moisture content, and density tests. The top inch of the final lift was carefully removed to provide a relatively smooth surface with no transverse grade. Results of tests made after construction of the subgrade had been completed are given as O-coverage data in table 1. These data were obtained from two CBR test pits that were excavated to a depth of 12 in. in the test section. An average subgrade CBR of 3.5 was obtained in the test section before traffic. Prior to mat placement, a polyethylene membrane was laid over the subgrade to deter drying, which would cause a change in strength.

Mat Placement

15. The mats were placed on the test section by an experienced mat-placing crew of six men under the direction of a foreman. The mats were stacked adjacent to the test section in open bundles to minimize the distance that panels had to be carried by the placing crew. A forklift maneuvered the bundles to keep the panels as close to the crew as practical. The panels were assembled into a test section by hinging the female side of a panel to the male side of a previously placed panel and dropping the panel into position. The end connection was secured by a connector bar slid into position in the end connector. The panels were placed with their longitudinal axes perpendicular to the direction of traffic and with the end joints staggered as shown in plate 1. No difficulties were encountered in placement operations. The placement rate for the Harvey mat was 370 sq ft per man-hour, which is slightly less than the essential rate of 400 sq ft per man-hour. The mat was seated in the subgrade with the same roller that was used to construct the subgrade. Lead weights, 2000 lb each, were placed along the sides of the test section to anchor the panels.

Test Load Cart

16. A specially designed single-wheel test cart (fig. 9) loaded to 30,000 lb was used in the traffic tests to simulate the loading conditions

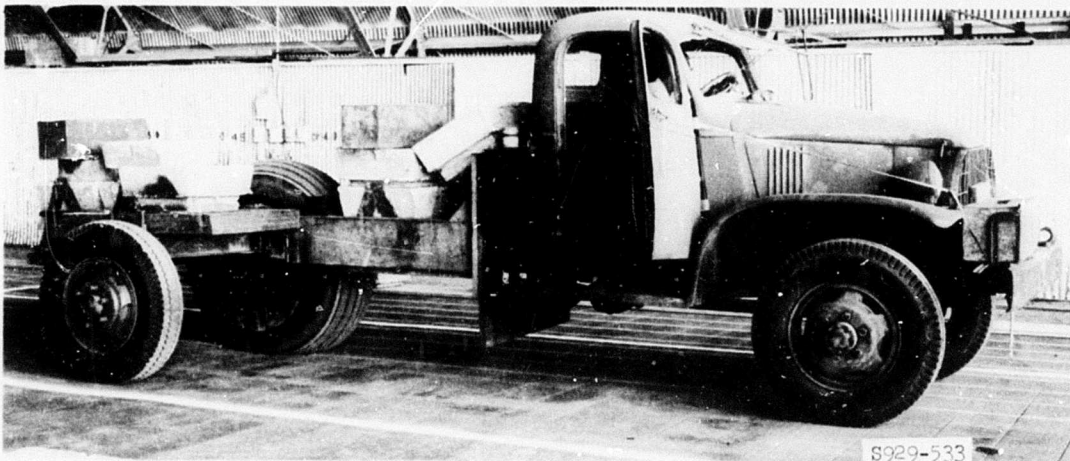


Fig. 9. Load cart used in traffic tests

of the C-130 aircraft. It was fitted with an outrigger wheel (load considered insignificant) to prevent overturning and was powered by the front half of a 4-wheel-drive truck. The test cart had a 20x20, 20-ply tire inflated to 100 psi, which produced a contact area of 328.6 sq in. and an average contact pressure of 91 psi.

Application of Traffic

17. Traffic was applied to simulate the traffic distribution pattern that would be encountered in actual aircraft takeoffs and landings. This pattern approaches a normal distribution curve.^{5,6} Traffic was started at one side of the test lane, and the load cart was driven forward and then backward in the same path for the length of the traffic lane. The path of the cart was shifted laterally 16.2 in. (the width of a tire print) on each successive forward trip. Thus, two coverages of the entire traffic lane were accomplished when the load cart was maneuvered from one side of the traffic lane to the other. The interior 97.2 in. of the traffic lane was then trafficked for six additional coverages. The longitudinal center 64.8 in. of the traffic lane then received two additional coverages, making a total of ten coverages for that particular area. The net result was that the center 64.8-in.-wide strip of the traffic lane received 100 percent of the traffic, the 16.2-in.-wide strips on each side of the center 64.8 in. received 80 percent, and the outside 16.2-in.-wide edge strips received only 20 percent (plate 3). This pattern of traffic application was repeated until mat failure occurred.

Skid Test Cart and Procedure

18. Skid tests were performed on both dry and wet surfaces. The skid vehicle used was the C-130 test cart loaded to 30,000 lb on a 20x20, 20-ply tire inflated to 100 psi. The truck section of the test cart was used only for steering, and a Tournadozer was used to pull the skid cart. In performance of the tests, the cart was positioned along one side of the traffic lane, and the wheel was locked to prevent rotation. The cart was

skidded over the mat at a uniform rate of speed for a given distance to determine the skid resistance offered by the mat surface and the tire wear resulting from the skidding.

PART IV: CRITERIA FOR MAT FAILURE AND DATA TAKEN

Failure Criteria

19. The following guidelines were used to determine failure of the mat:

a. Excessive mat breakage.

- (1) Weld failure: when the weld failure appreciably affects the performance of the mat or becomes a tire hazard.
- (2) Rib failure: when the rib failure appreciably affects the performance of the mat or causes undue roughness.
- (3) End-joint failure.
- (4) Breaks.
 - (a) A panel was considered failed when a break was considered to be a tire hazard.
 - (b) A section was considered failed when breaks exceeding 6 in. in length occurred in 50 percent of the panels, or when breaks extending 40 percent of the length of a panel occurred in 20 percent of the panels.

b. Static deflection, 1 in. maximum.

c. Roughness.

- (1) Deflection not to exceed 1 in. at side joint. Measurement to be made from a 4-ft-long straightedge.
- (2) Dishing not to exceed 0.6 in.
- (3) Uneven mat surface and instability of the test vehicle as determined by visual observations and experienced judgment when the test vehicle was traveling at a uniform speed (approximately 2 to 4 mph).

20. It was assumed that a certain amount of maintenance would be performed in the field during usage of the mat. For engineer traffic tests, it is considered feasible to replace up to 10 percent of the panels in the traffic lane (i.e., that portion receiving 100 percent of the coverages) with new panels during a test. When an additional panel required replacement or was considered to be a tire hazard, the section was considered failed.

Types of Data Recorded

Skid Tests

21. The force required to pull the skid cart with locked wheel over the mat surface was measured with an electric recording dynamometer with a capacity of 50,000 lb. Recordings of the force required to pull the skid cart and of the distance of the skid were made on individual oscillograms. Comparative tire wear was estimated by visual observations supplemented by photographs. Observations and photographs of the antiskid coating on the mat were made before and after the skid tests.

Traffic tests

22. Subgrade densities, water contents, and in-place CBR's measured prior to, during, and at the conclusion of traffic are shown in table 1. These soil tests were made at the surface of the subgrade and at depths of 6 and 12 in., with a minimum of three tests per depth. Static deflections of the mat were measured with the load wheel at the joints and center points of panels; results are shown in plate 4. Level readings (transverse and longitudinal) were taken prior to and at the completion of traffic to measure permanent deformation of the sections and to reveal the development of roughness. These readings are shown in plates 5 and 6. Visual observations of the mat, subgrade behavior, and other relevant factors were recorded throughout the test period of traffic and were supplemented by photographs. Pertinent data will be discussed later in the report.

PART V: SKID AND TRAFFIC TEST RESULTS AND ANALYSIS

Test Results

Skid tests

23. Skid tests were conducted on the panels prior to traffic tests. The skid cart previously described was used on both a dry and a wet surface. A summary of the test results is tabulated below:

<u>Skid No.</u>	<u>Panel Condition</u>	<u>Length of Skid, ft</u>	<u>Average Pull Force, lb</u>	<u>Coefficient of Friction</u>
1	Dry	13.0	22,000	0.73
2	Wet	13.0	18,500	0.62

The data above show the difference between the coefficient of friction on a dry surface and that on a wet surface (QMR, 2 April 1968, specifies a runway coefficient reading (RCR) of 13-25, which is equivalent to a coefficient of friction between 0.4 and 0.8 on a dry or wet coated surface). In the skid test on the dry panels, no antiskid coating was removed from the mat, but a considerable amount of rubber from the tire was left on the mat. Photograph 1 shows the skid marks after the skid test on the dry panels. A small amount of antiskid coating was removed from two panels during the skid test on the wet panels. Photograph 2 shows the skid marks after the skid test on the wet panels.

Traffic test

24. A general view of the test section prior to traffic is shown in photograph 3. Prior to the application of traffic, the average CBR of the subgrade was 3.5, and the mat surface was generally smooth. Traffic was applied using the test load cart previously described. After 70 coverages, slight depressions were observed at the center of seven panels. These depressions increased as traffic was applied over the test lane.

25. Traffic was continued in a normal pattern to 200 coverages (photograph 4). Photograph 5 shows a depression in panel 45 after 200 coverages. At 254 coverages, a 1-1/2-in. split occurred in the top skin of panel 22. This split was 11/16 in. away from and parallel to the female rail of the panel and had increased to 9-1/2 in. by 300 coverages. Panels 25, 28, 34, 40, 46, and 55 contained depressions in the top skins 11/16 in.

away from and parallel to the female rail, but no splits were visible. A general view of the test section after 340 coverages is shown in photograph 6. Photograph 7 shows the splits and depressions in the top skins of panels 22 and 25 after 340 coverages. Depressions in almost all other panels were also noticeable.

26. Traffic was continued in a normal pattern to 400 coverages (photograph 8). After 400 coverages, 11 panels contained breaks in the top skin adjacent to the female rail. These breaks were 4-1/2 to 29 in. long. Panels 22, 25, 43, 46, 52, and 55 had breaks in the top skins, which indicated that internal rib failures had occurred, and these panels were considered failed at 400 coverages. Photographs 9 and 10 show closeup views of the breaks in the top skins adjacent to the female connectors of panels 22 and 25 and 52 and 55, respectively, after 400 coverages. These breaks were tire hazards. In addition to the six failed panels, panels 28, 31, 34, and 37 had splits but were not considered failed at 400 coverages.

27. As explained in paragraph 20, for engineer traffic tests, the total number of panels that can be replaced in the traffic lane is equal to 10 percent of the number receiving 100 percent of the traffic. When an additional panel requires replacement or is considered to be a tire hazard, the section is considered failed. In this test, 60 panels were in the 100 percent traffic area of the lane. Therefore, the six failed panels could be replaced, but when an additional panel failed, the section would be considered failed.

28. When traffic was continued after the mats were inspected after 400 coverages, popping and crackling noises could be heard as the load wheel moved over the section from run 19 (see plate 1) north. These noises indicated internal rib failures. Traffic was stopped at 450 coverages because six additional panels had splits in the top skins that were tire hazards (photograph 11). Since more than 10 percent of the panels in the 100 percent traffic area had failed, the test section was considered failed after 450 coverages. Photograph 12 shows the test section after 450 coverages.

29. Failed panels were removed from the test section and photographed to illustrate the external damage to the mat. Panels that showed

evidence of internal rib failure were then sawed to expose a cross section of the mat structure. Photographs 13 and 14, respectively, show a break in the top skin of panel 19 adjacent to the female connector and a cross-section view of failures in panel 19. Photograph 15 shows breaks in top skins at the female edges of panels 25 and 28. Photograph 16 shows a bow of approximately 3 in. in a 12-ft-long panel. Photographs 17 and 18, respectively, show a break in the top skin of panel 37 along the female edge and breaks and damage in the bottom skin of panel 37. Photographs 19 and 20, respectively, show a break in the top skin of panel 43 and breaks in and indentation of the bottom skin in panel 43. A cross-section view of internal rib failures in panel 43 is shown in photograph 21. Photograph 22 is a cross-section view of panel 45 showing rib failure. A cross-section view of panel 49 showing rib failures is shown in photograph 23.

30. Static deflection measurements made at 0 and 450 coverages are shown in plate 4. Cross sections made at 0 and 450 coverages are shown in plate 5, and permanent deformation profiles are shown in plate 6. Maximum static deflection, which occurred at the quarter point of panel 46, was approximately 1.10 in. Maximum permanent depression of the cross sections was approximately 0.70 in. in the 100 percent traffic lane area. Maximum permanent deformation was approximately 0.80 in. along the center line of the traffic lane.

31. Except for the failed panels, the surface of the test section through run 13 was still relatively smooth at the end of traffic. The average CBR after 450 coverages was 4.9, and the rated CBR for the test section was 4.2.

Analysis of Results

General

32. The placement rate for the mat was 370 sq ft per man-hour on a flat subgrade. This low rate is at least partially attributed to the geometry of the mat; the panel area is only 12 sq ft, which is only half the size of standard extruded mats such as XM18 and AM2. Although the mat is smaller, two men are still required for placement.

33. The coefficients of friction on the dry and wet surfaces meet the requirements of the revised QMR (RCR of 13-25, or coefficient of friction of 0.4-0.8).

34. All of the mat panel failures in the 100 percent traffic area were due to top skin breaks adjacent to the connectors, internal rib breaks, and breaks and deformation of the bottom skin. This indicates that (a) additional strength is needed in all of these areas to improve the performance of the mat, and (b) no one area of the extrusion appeared to be stronger than any other area.

Mat strength evaluation

35. Actual CBR, load, tire pressure, and coverages were used in the following equation* to derive the number of coverages that the Harvey light-duty mat would withstand if placed on a 4-CBR subgrade.

$$\frac{t}{0.23 \log_{10} (C) + 0.15} = \sqrt{P \left(\frac{1}{8.1 \text{ CBR}} - \frac{1}{p\pi} \right)}$$

where

t = design thickness of pavement structure, in.

C = coverages at failure (450)

P = total wheel (or equivalent wheel) load, lb (30,000)

CBR = rated California Bearing Ratio of subgrade (4.2)

p = tire pressure, psi (100)

Solution of the equation indicated that the Harvey light-duty mat on a 4-CBR subgrade would withstand 367 coverages of traffic when subjected to a 30,000-lb single-wheel load with a tire inflation pressure of 100 psi. The strength evaluation of the Harvey light-duty mat is shown graphically in plate 7. The curve indicates that for the Harvey mat to survive the 1000 coverages required for light-duty loading, a CBR of 5 would be necessary.

* This is a combination of equation 2, page 2, and the equation for slope of curve, plate 3, from reference 7.

PART VI: LABORATORY TESTS

36. Laboratory tests were performed on the Harvey mat to determine its load-carrying capacity and to determine the mechanical properties of the as-extruded 6063-T6 alloy for comparison with standard requirements for the alloy and for comparison with the mechanical properties of 6061-T6 aluminum alloy.

Test Equipment

37. Both beam flexural strength tests and tensile tests of the Harvey light-duty mat were performed on a 60,000-lb-capacity testing machine. The tensile tests were performed using an extensometer of 2-in. gage length to determine the percentage of elongation.

Tests and Results

Test specimens

38. The beam flexural tests were conducted on standard half panels selected at random, and the tensile tests were performed on samples that had been cut from standard panels selected at random.

Test procedures

39. The flexural strength, or load per foot, was determined on 60-in. spans utilizing quarter-point loading of a simple beam. The specimens tested were standard half panels (approximately 6 ft long and 1 ft wide). The yield and ultimate tensile strengths and percentage of elongation of the as-extruded 6063-T6 aluminum alloy were determined by tensile testing of nine specimens. Three specimens each were cut from the top skins, vertical webs, and bottom skins of panels.

Results

40. A curve showing the average load-carrying capacity of the Harvey mat per foot of width is shown in plate 8. The specimens did not show any visible structural breaks during the test, but continued to deflect with an increase in loading. Minor localized dimpling occurred under the loading

points. The specimens retained approximately 2-5/8-in. permanent set after testing. Table 2 shows the average yield and ultimate strengths of the 6063-T6 alloy compared with the tensile strength requirements for both 6061-T6 and 6063-T6 alloys as specified in reference 4. The average yield strength for the Harvey mat specimens was 31,700 psi, the average ultimate strength was 35,000 psi, and the average elongation was 8.2 percent. These results indicate that the 6063-T6 extruded aluminum alloy material as supplied exceeded the minimum requirements specified in reference 4. Therefore, the low coverage rating of the mat could not be attributed to the quality of the 6063-T6 alloy, although the alloy is of lower strength than the 6061-T6 alloy.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

41. Based on the results obtained from the investigation of the Harvey light-duty mat, it was determined that the mat failed to comply with the QMR structural requirements and placing rates. Specific examples of the deficiencies are as follows:

- a. The placement rate of 370 sq ft per man-hour on a flat subgrade failed to meet the requirement of 400 sq ft per man-hour for light-duty mat.
- b. The mat as fabricated will support 367 coverages of a single-wheel load on a subgrade with a CBR of 4.0, which fails to meet the project traffic criterion of 1000 coverages.
- c. The weight per square foot of placing area (3.09 lb) exceeded the essential weight requirement (3.0 lb per square foot of placing area).

42. The mat was considered adequate with respect to antiskid performance and tire wear. Tire wear during the dry skid test was noticeable, but the performance of the antiskid compound was considered adequate, as determined by coefficient of friction tests. Laboratory-determined properties of the 6063-T6 extruded aluminum alloy EB welded mat exceeded the specified mechanical properties for this alloy.

Recommendations

43. Based on the results obtained in this investigation, it is recommended that the cross-section configuration of the Harvey light-duty mat be changed to determine if additional strength can be obtained in the radii and internal ribs.

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2. Rood, R. L. and Mecca, M. A., "Operational Test and Evaluation of T11 Aluminum Landing Mat," Technical Report No. 63-34, Oct 1964, U. S. Air Force Tactical Air Command, Langley Air Force Base, Va.
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4. American Society for Testing and Materials, "Aluminum-Alloy Extruded Bars, Rods, Shapes, and Tubes," Designation: B 221-69, 1969 Book of ASTM Standards, Part 6, 1969, Philadelphia, Pa., pp 171-182.
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6. U. S. Army Engineer Waterways Experiment Station, CE, "Study of Channelized Traffic," Technical Memorandum No. 3-426, Feb 1956, Vicksburg, Miss.
7. Ahlvin, R. G., "Developing a Set of CBR Design Curves," Instruction Report No. 4, Nov 1959, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

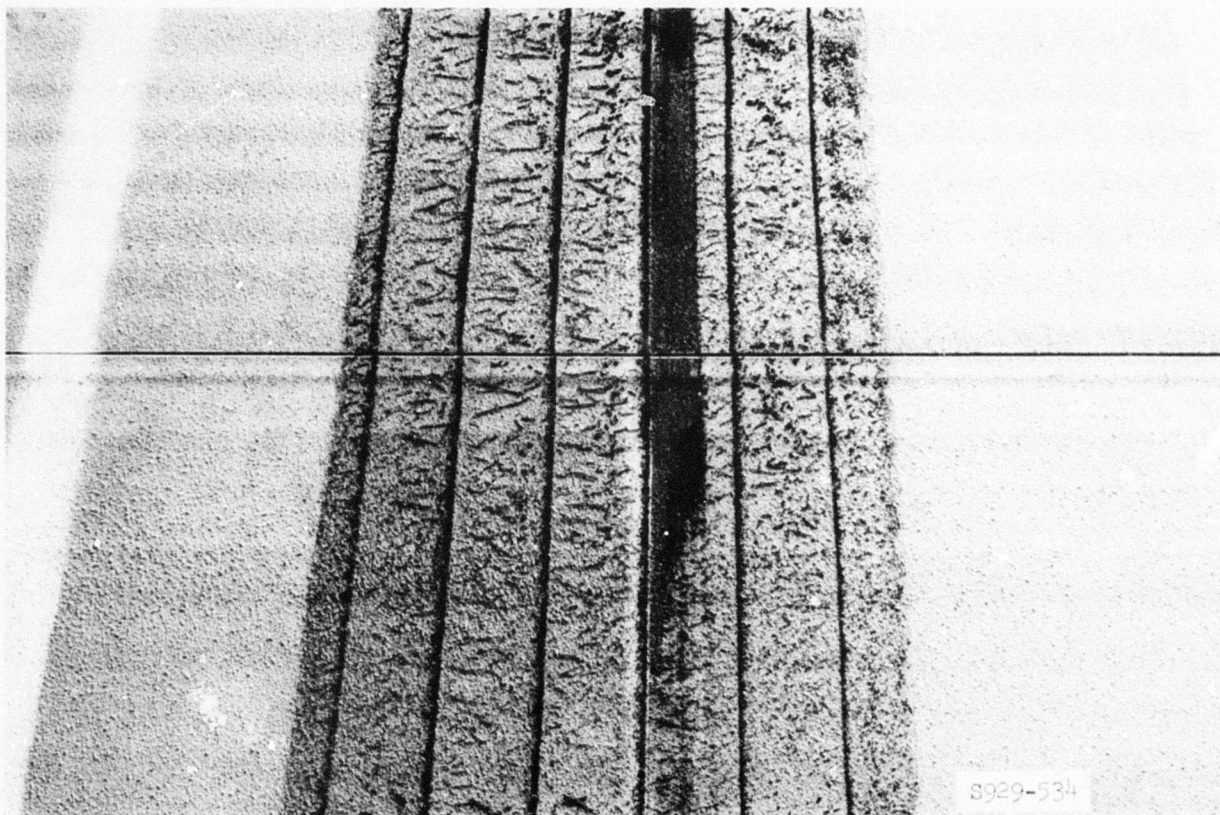
Table 1
Summary of CBR, Water Content, and Density Data

No. of Coverages	Station	Depth in.	CBR	Water Content %	Dry Density pcf	Average CBR for Coverage Level	Rated CBR
0	0+15	Surface	3.5	30.3	88.0	3.5	
		6	3.8	30.5	86.8		
		12	4.1	29.8	87.9		
		Avg	3.8	30.2	87.6		
	0+25	Surface	3.4	29.8	87.9		
		6	2.9	31.3	85.4		
		12	3.3	30.0	88.3		
		Avg	3.2	30.4	87.2		
	0+07	Surface	6.0	29.6	90.8		
		6	6.0	29.6	90.2		
		12	5.0	30.2	88.8		
		Avg	5.7	29.8	89.9		
450	0+30	Surface	4.8	30.0	88.8	4.9	4.2
		6	3.2	32.0	86.3		
		12	4.1	30.7	88.6		
		Avg	4.0	30.9	87.9		

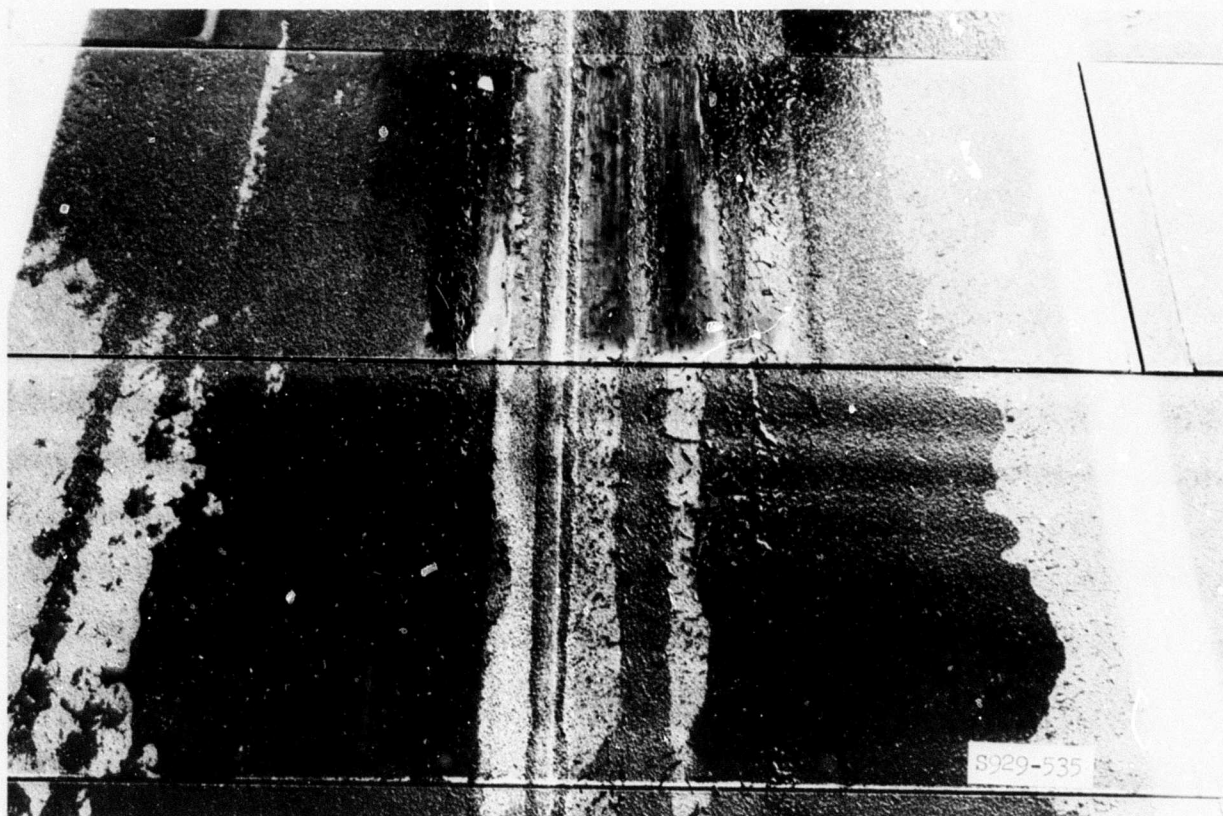
Table 2
Laboratory Test Data

	Handbook*		Test Results
	Requirements		
	<u>6061-T6</u>	<u>6063-T6</u>	
			<u>6063-T6</u>
Tensile strength, psi			
Yield	35,000	25,000	31,700
Ultimate	38,000	30,000	35,000
Elongation, percent			
minimum in 2 in.	8.0	8.0	8.2

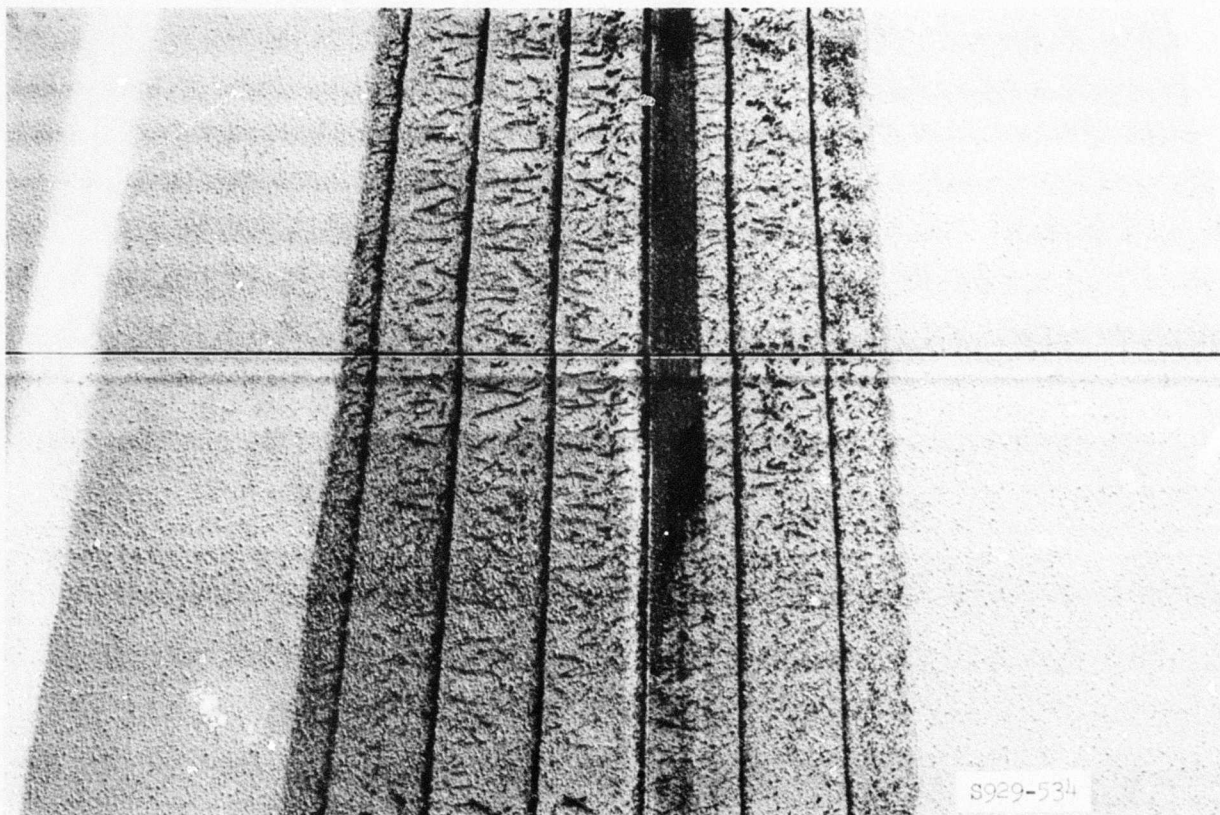
* Minimum requirements given in reference 4.



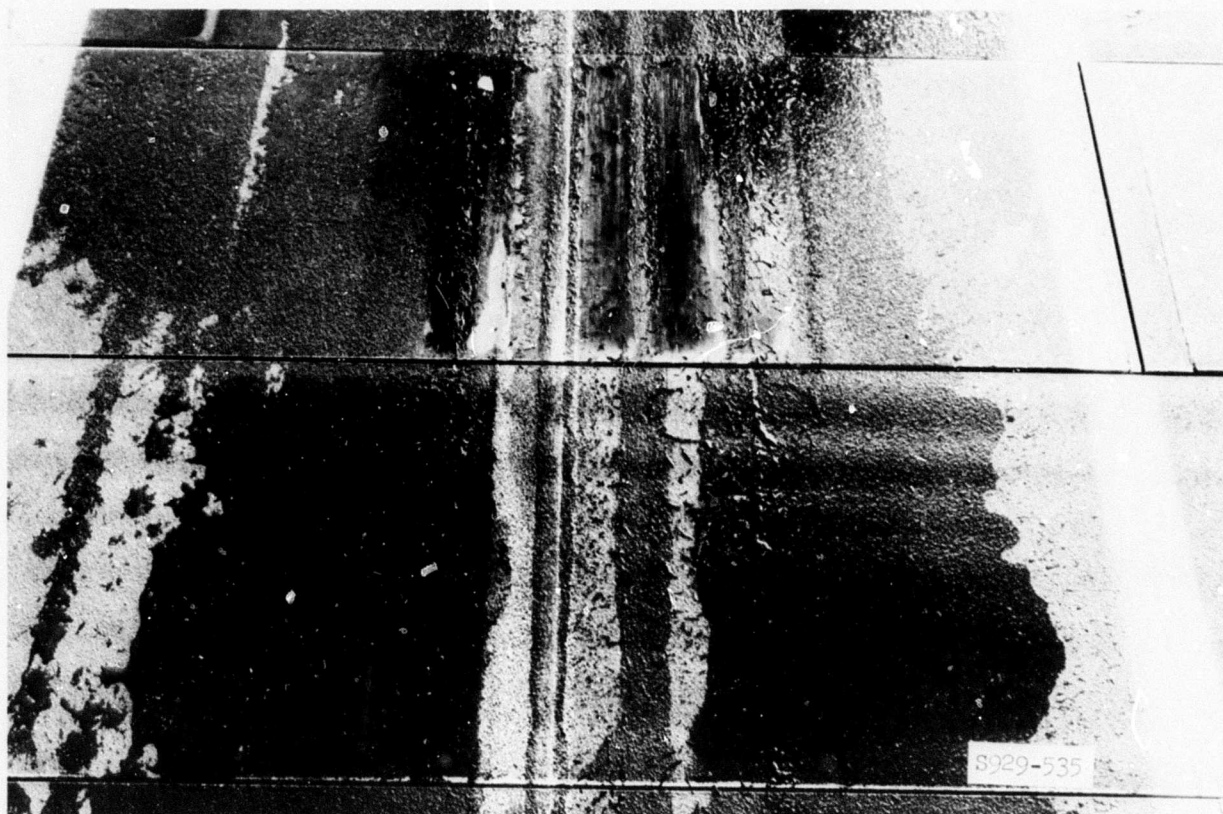
Photograph 1. Tire rubber on mat surface after skid test on dry panels



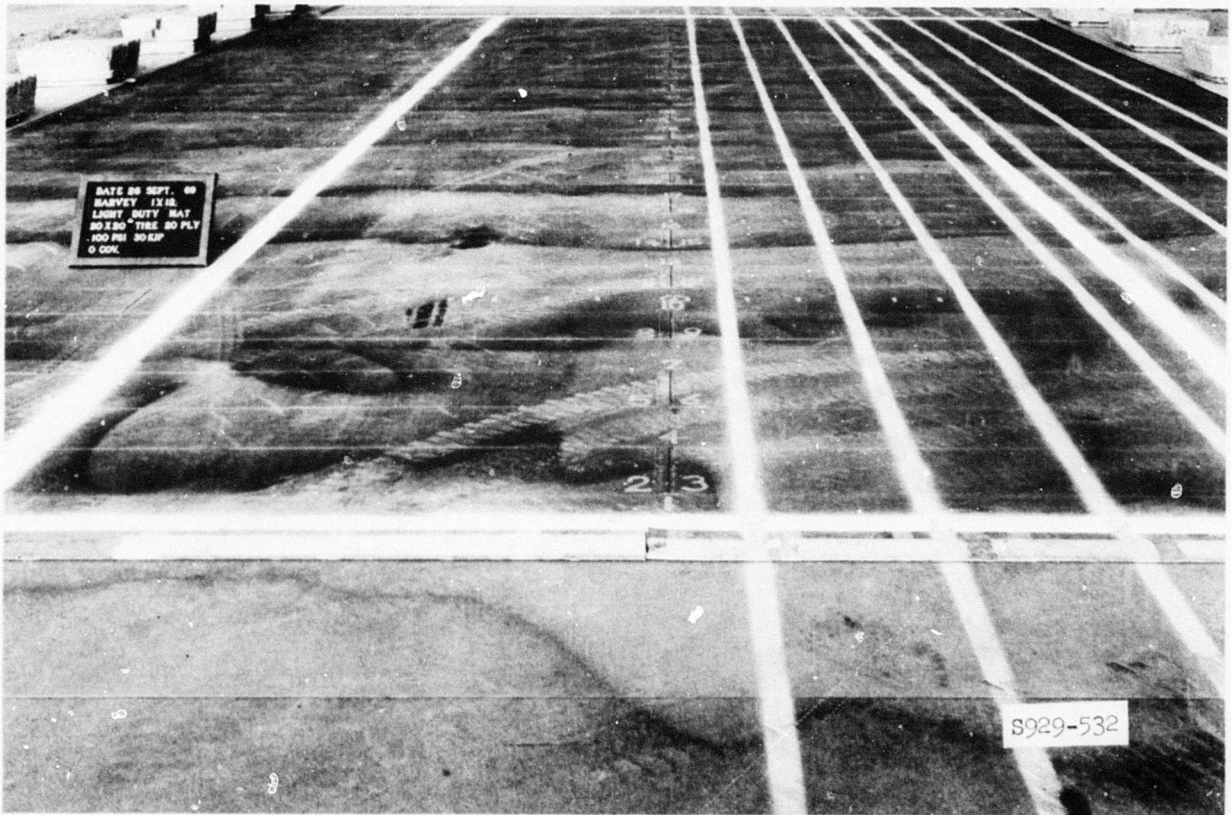
Photograph 2. Mat surface after skid test on wet panels



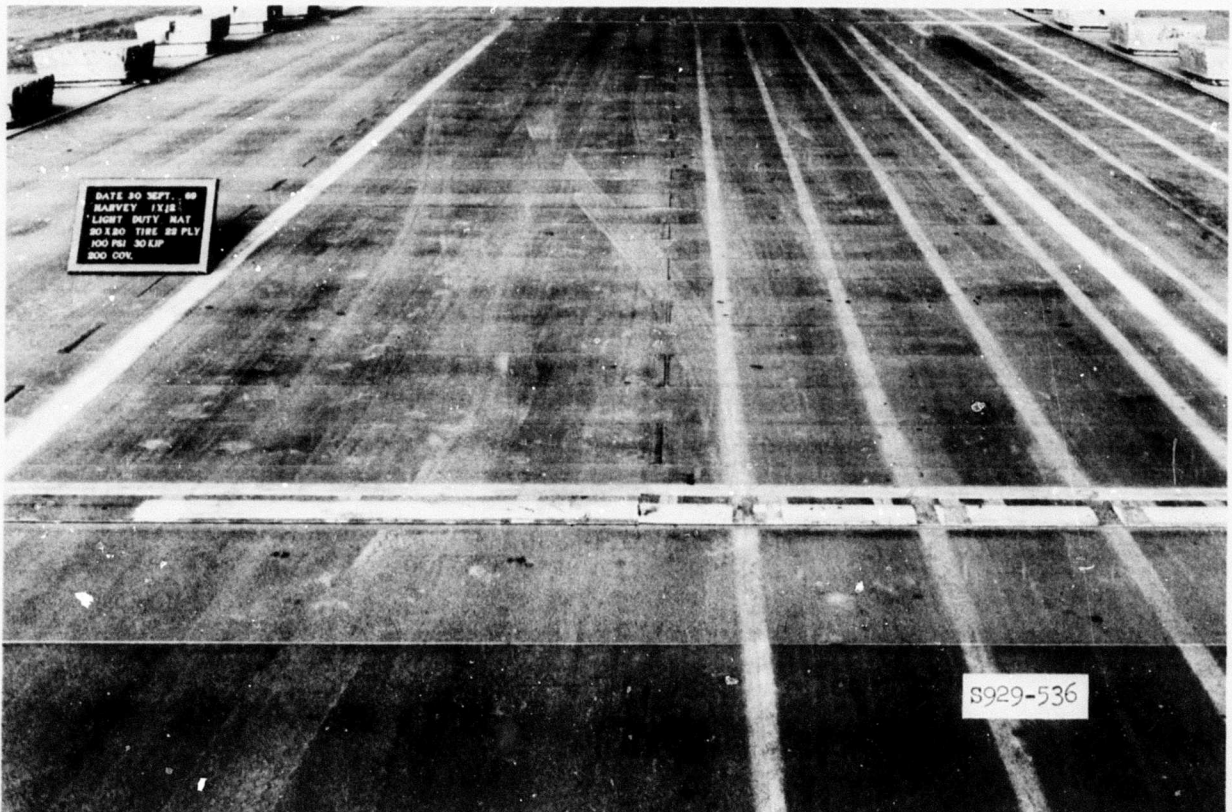
Photograph 1. Tire rubber on mat surface after skid test on dry panels



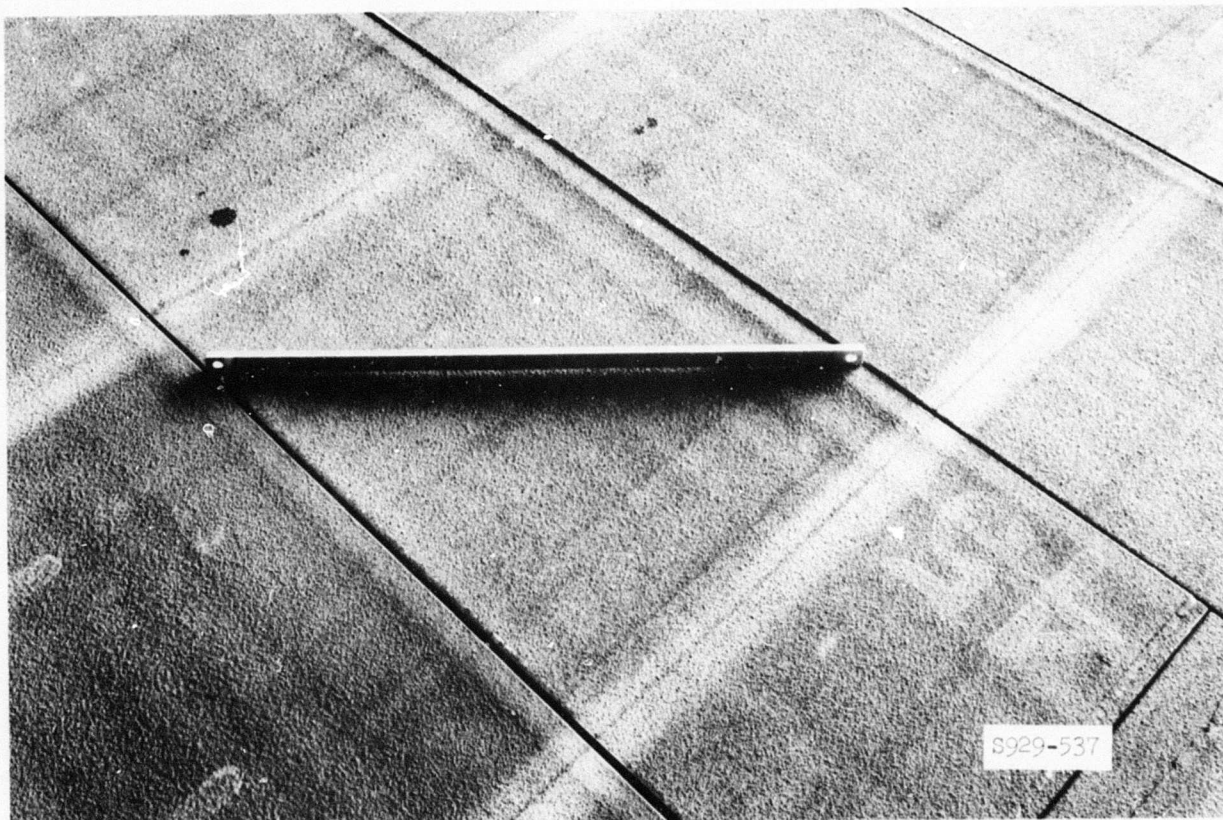
Photograph 2. Mat surface after skid test on wet panels



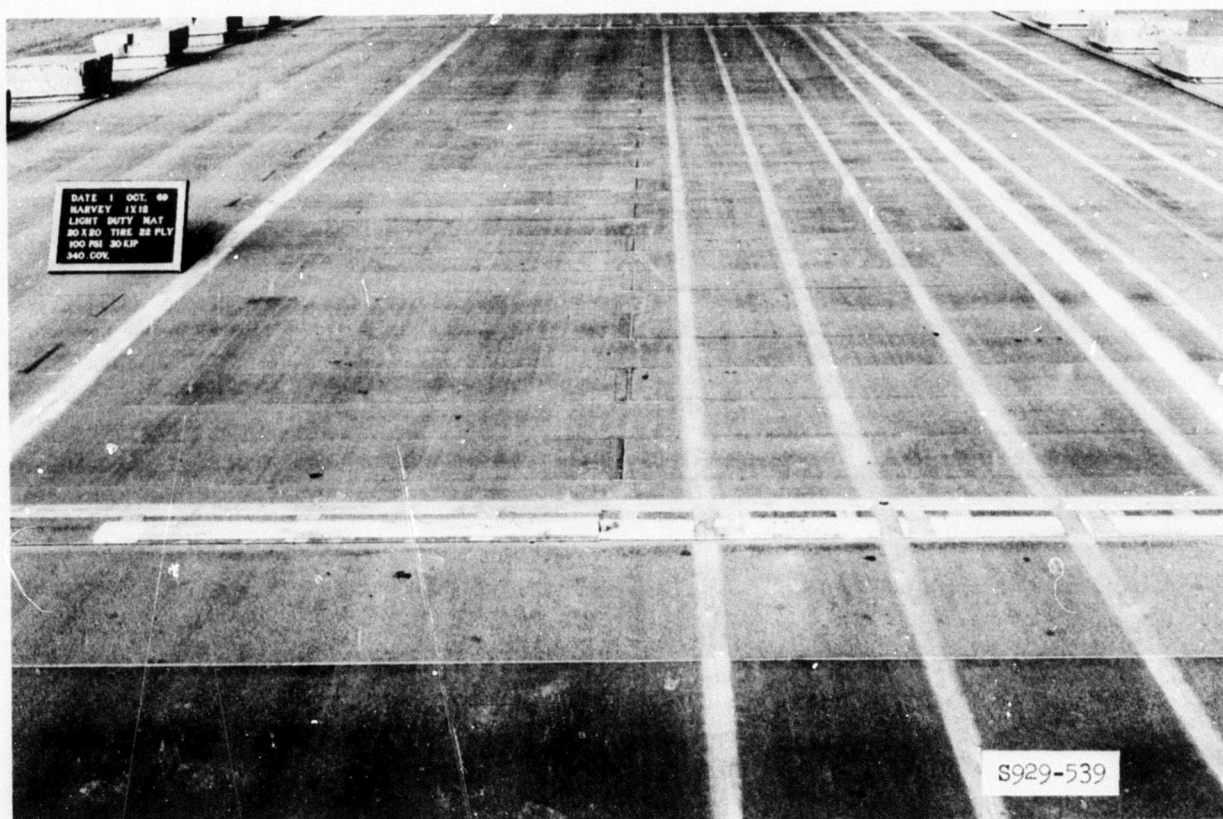
Photograph 3. Test section prior to traffic



Photograph 4. Test section after 200 coverages



Photograph 5. Depression in panel 45 after 200 coverages



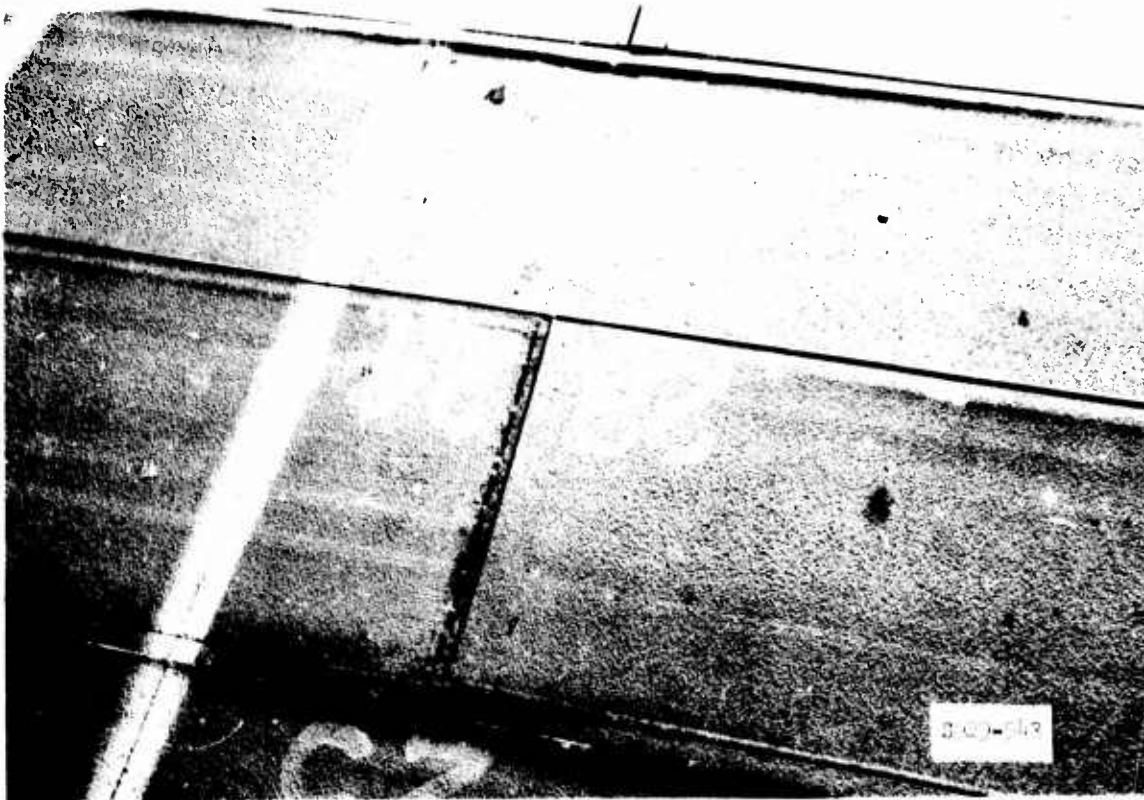
Photograph 6. Test section after 340 coverages



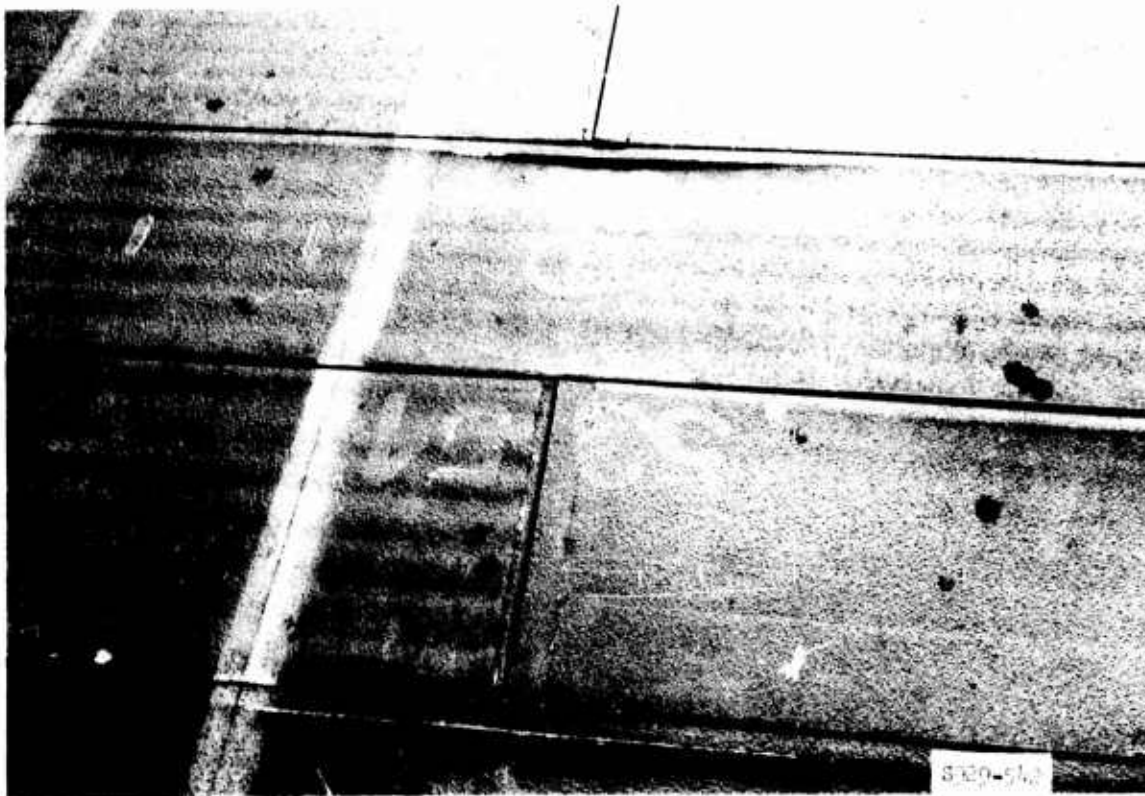
Photograph 7. Splits and depressions in the top skins of panels 22 and 25 after 340 coverages



Photograph 8. Test section after 400 coverages



Photograph 9. Breaks in the top skins adjacent to the female connectors of panels 22 and 25 after 400 coverages



Photograph 10. Breaks in the top skins adjacent to the female connectors of panels 52 and 55 after 400 coverages



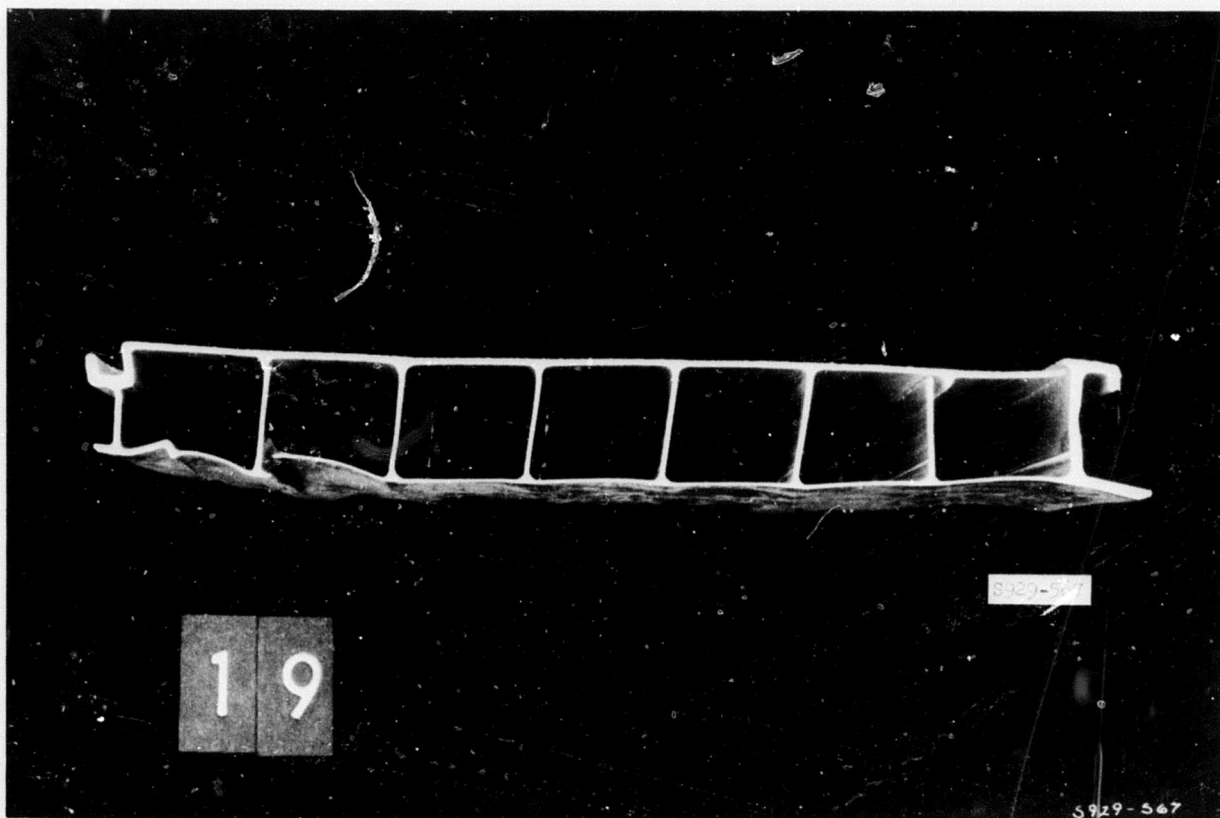
Photograph 11. Splits in top skin of mat after 450 coverages



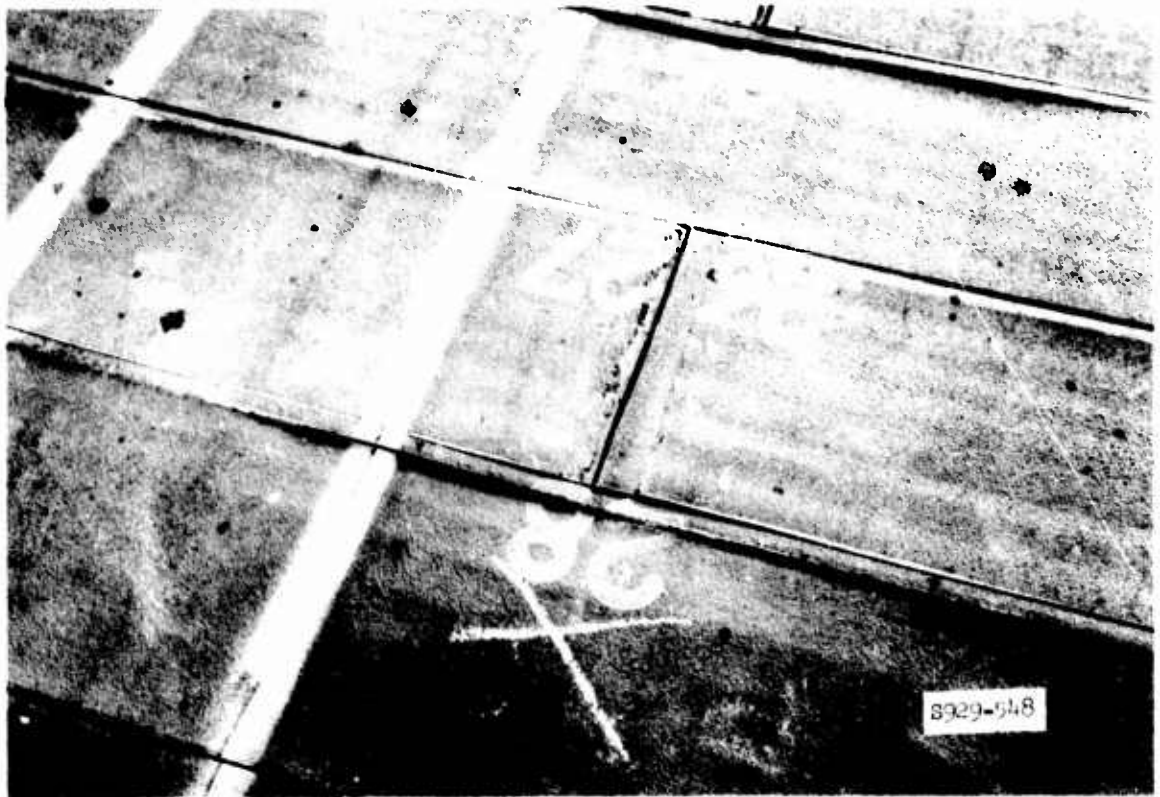
Photograph 12. Test section after 450 coverages



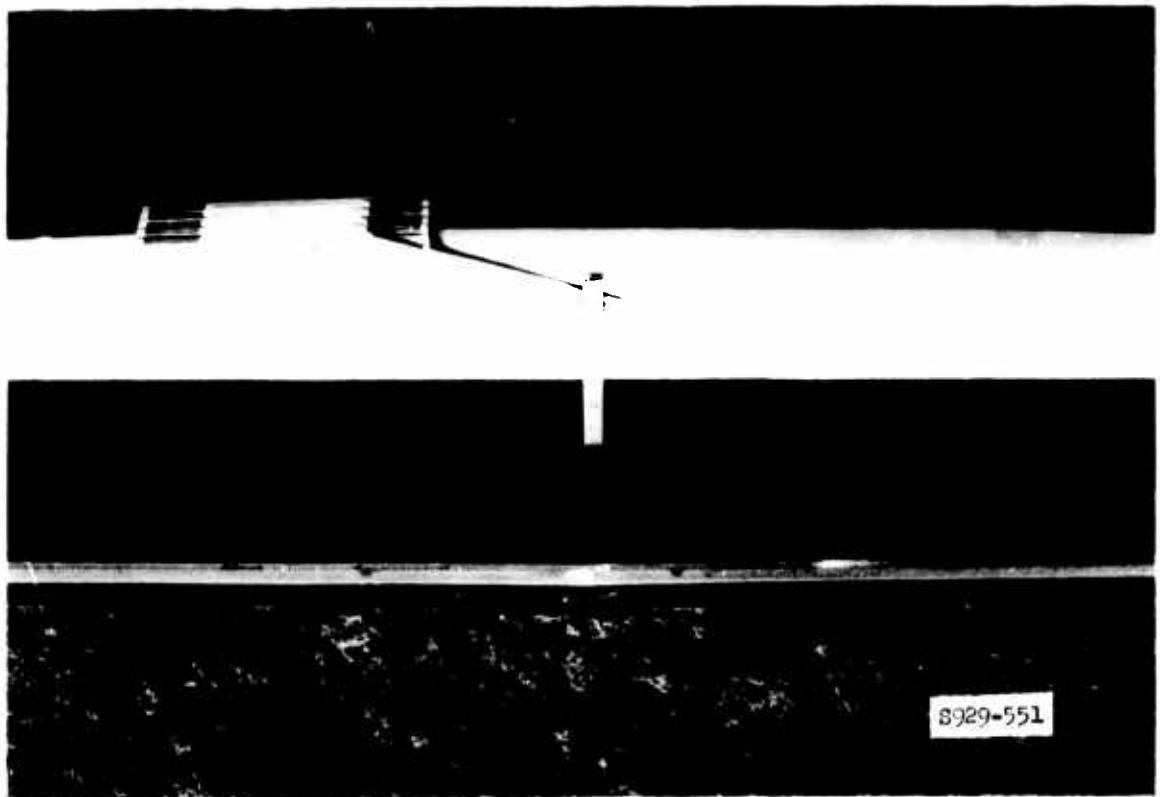
Photograph 13. Break in top skin of panel 19 adjacent to female connector after 450 coverages



Photograph 14. Cross-section view of failures in panel 19, which was removed from the section after 450 coverages



Photograph 15. Breaks in top skins at female edge of panels 25 and 28 after 450 coverages



Photograph 16. Bow in full panel after 450 coverages



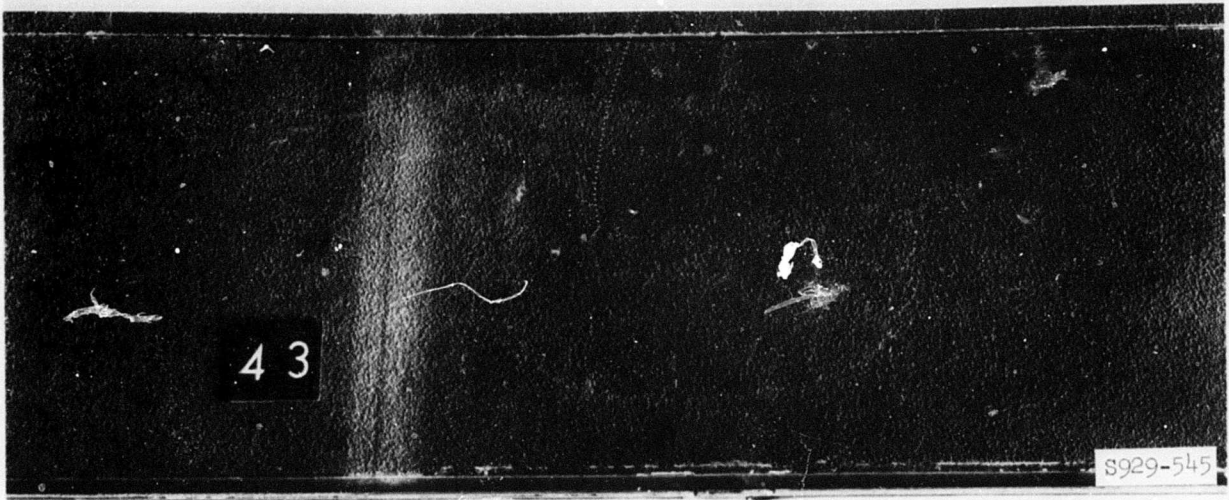
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Photograph 17. Break in top skin of panel 37 after 450 coverages

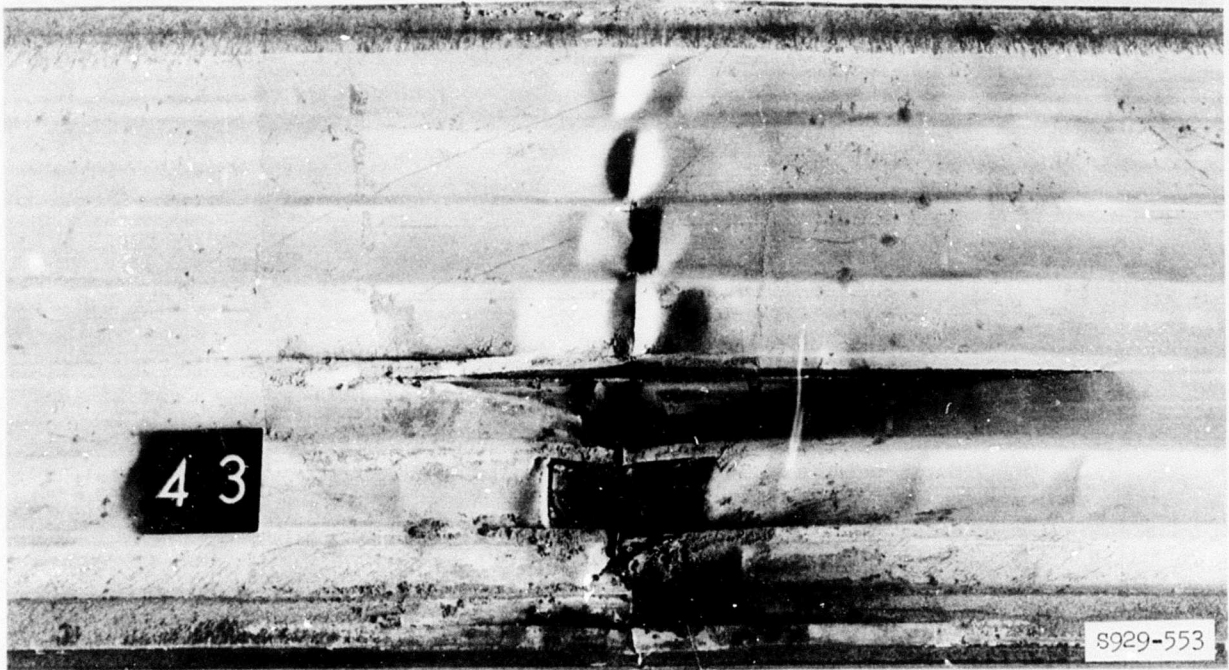


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Photograph 18. Failures in bottom skin of panel 37 after 450 coverages



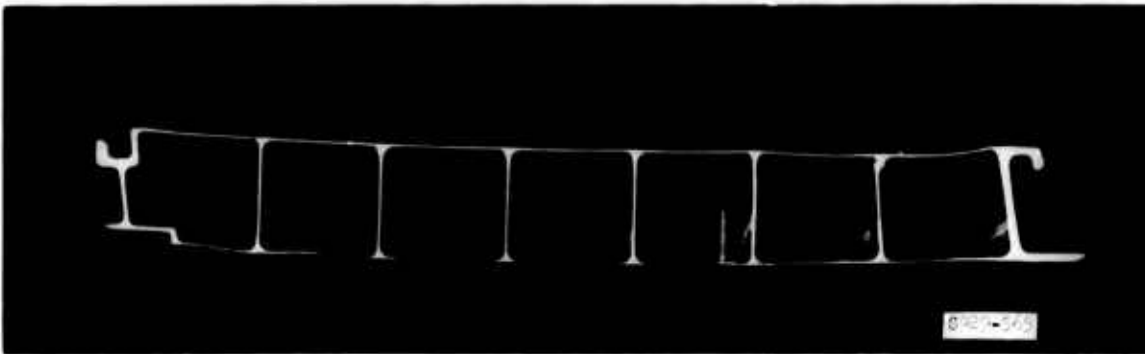
Photograph 19. Break in top skin of panel 43 after 450 coverages



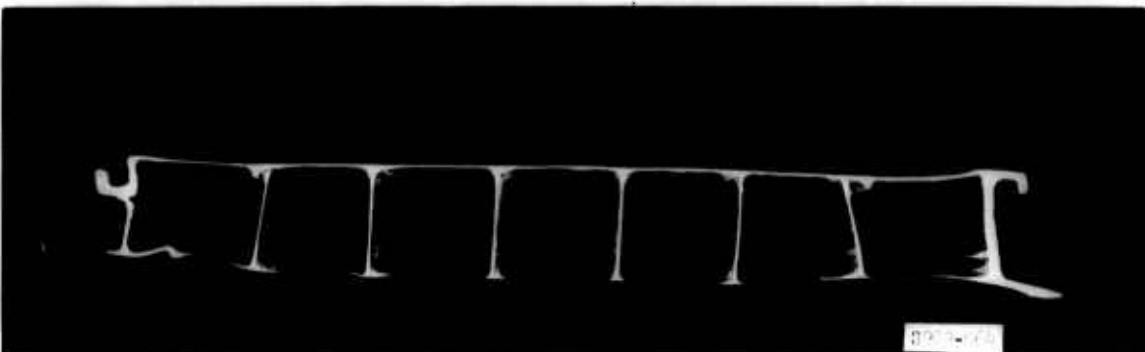
Photograph 20. Failures in bottom skin of panel 43 after 450 coverages



Photograph 21. Cross-section view of internal rib failures in panel 43 after 450 coverages

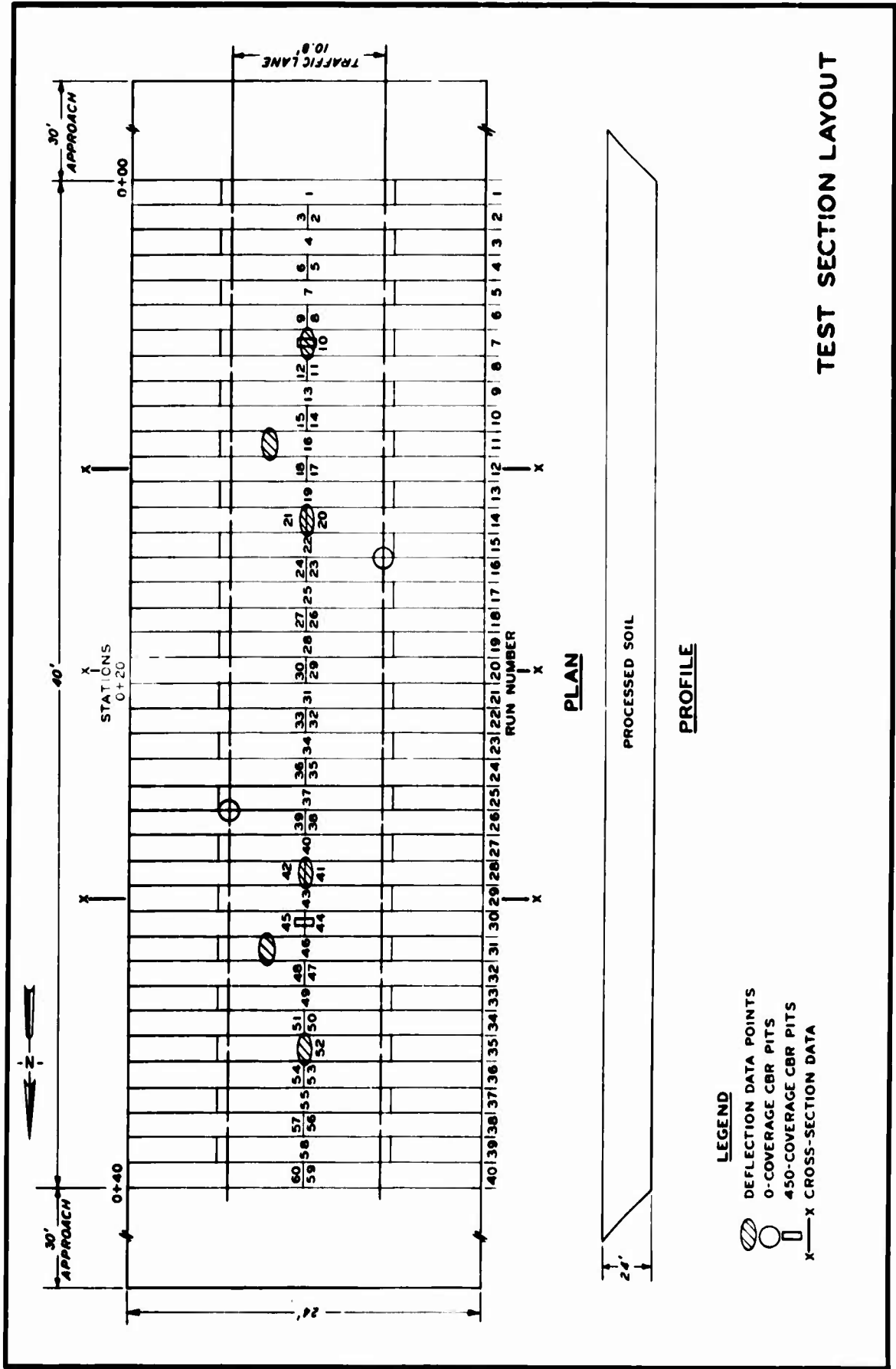


Photograph 22. Cross-section view of panel 45 showing rib failure after 450 coverages



Photograph 23. Cross-section view of panel 49 after 450 coverages

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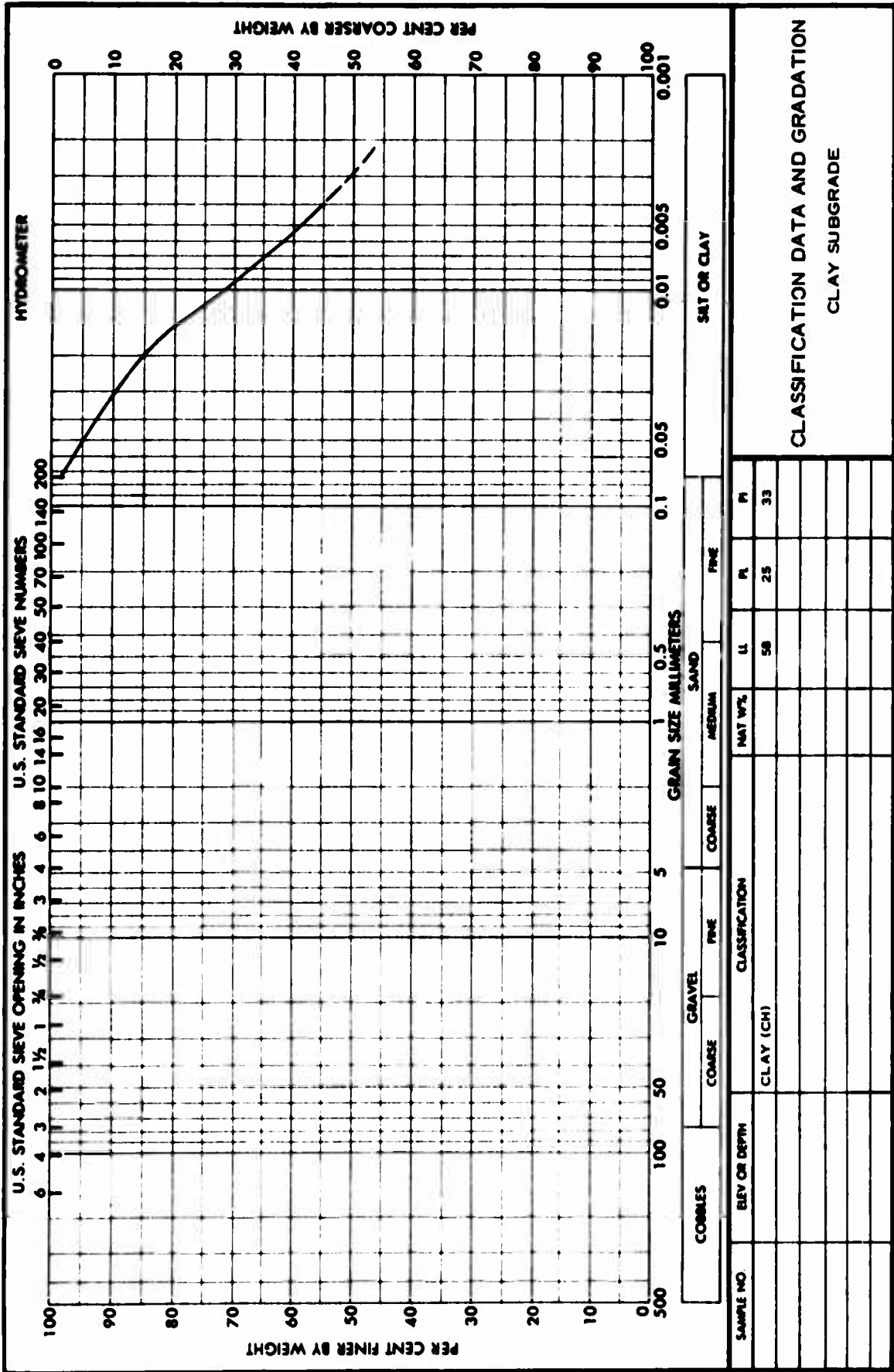
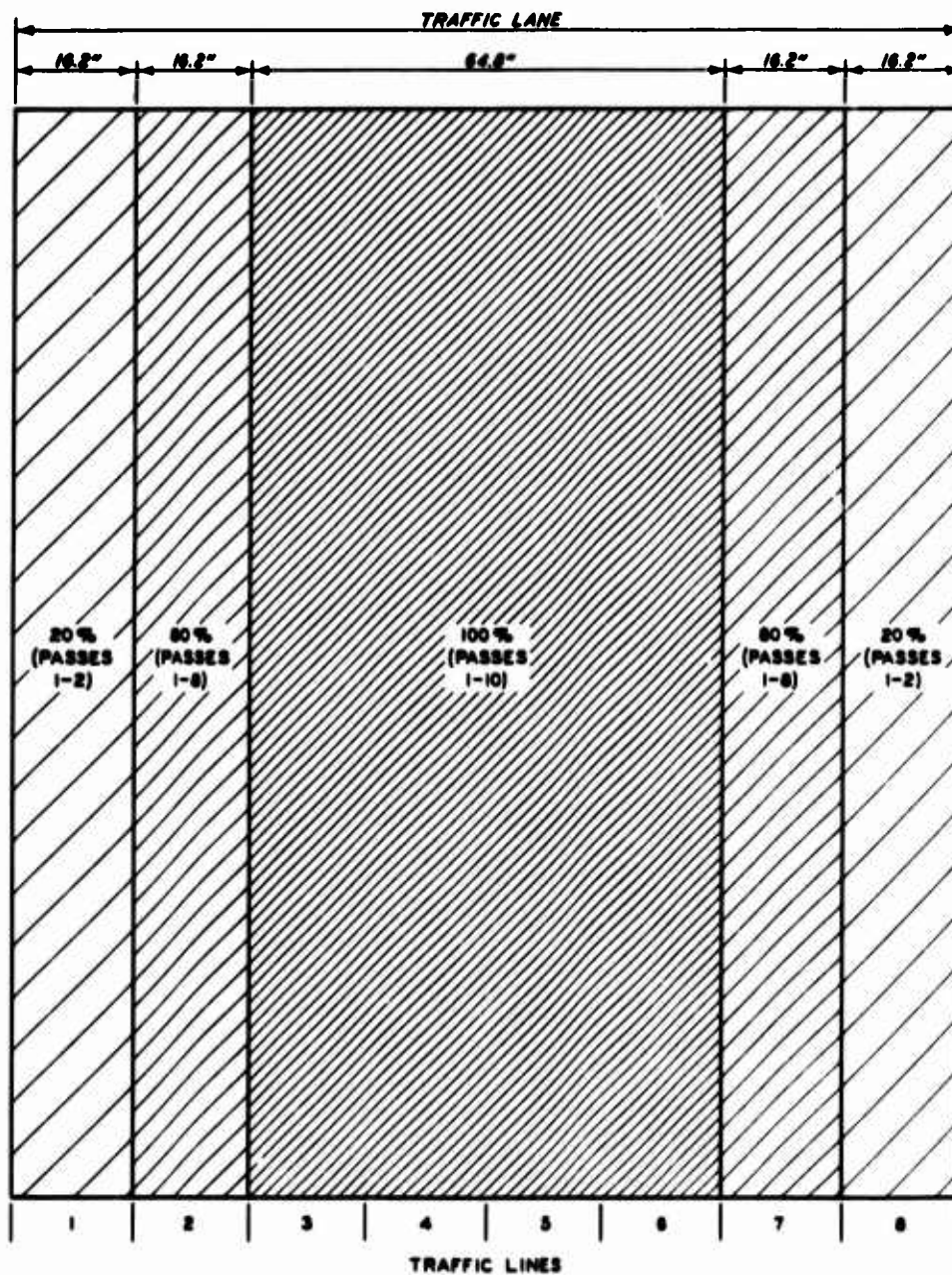
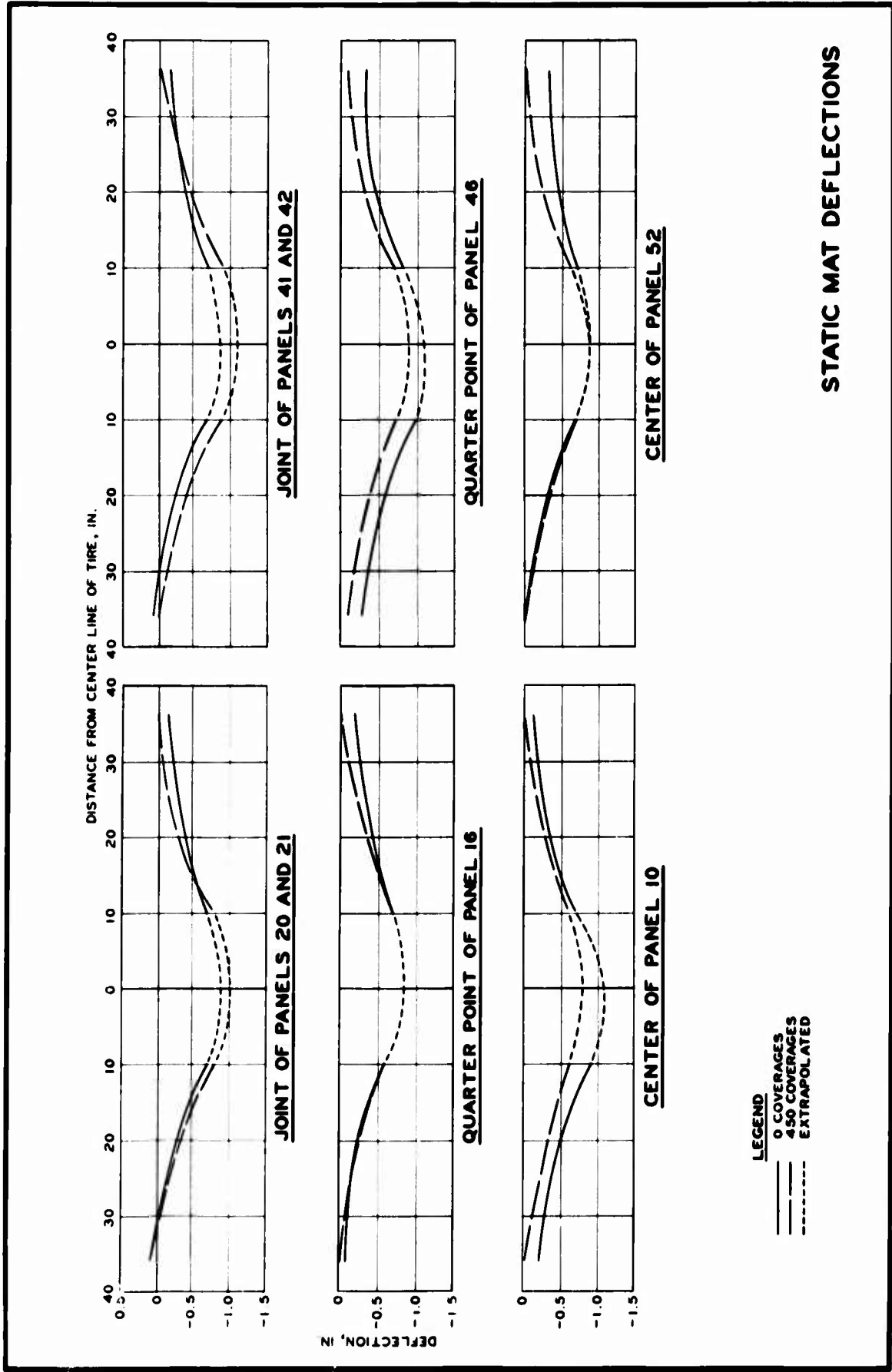


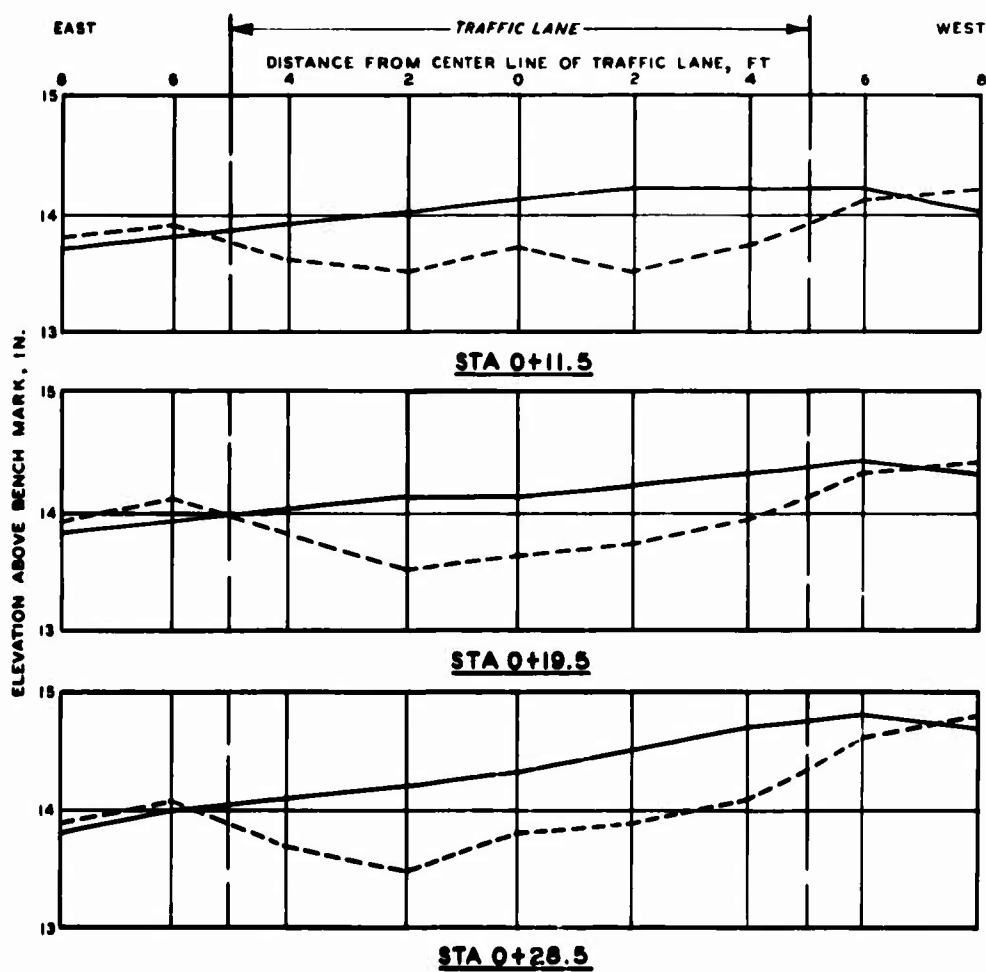
PLATE 2



NOTE: EACH PASS IS EQUAL TO A COVERAGE
BY THE 16.2-IN.-WIDE WHEEL OVER
EACH TRAFFIC LINE.

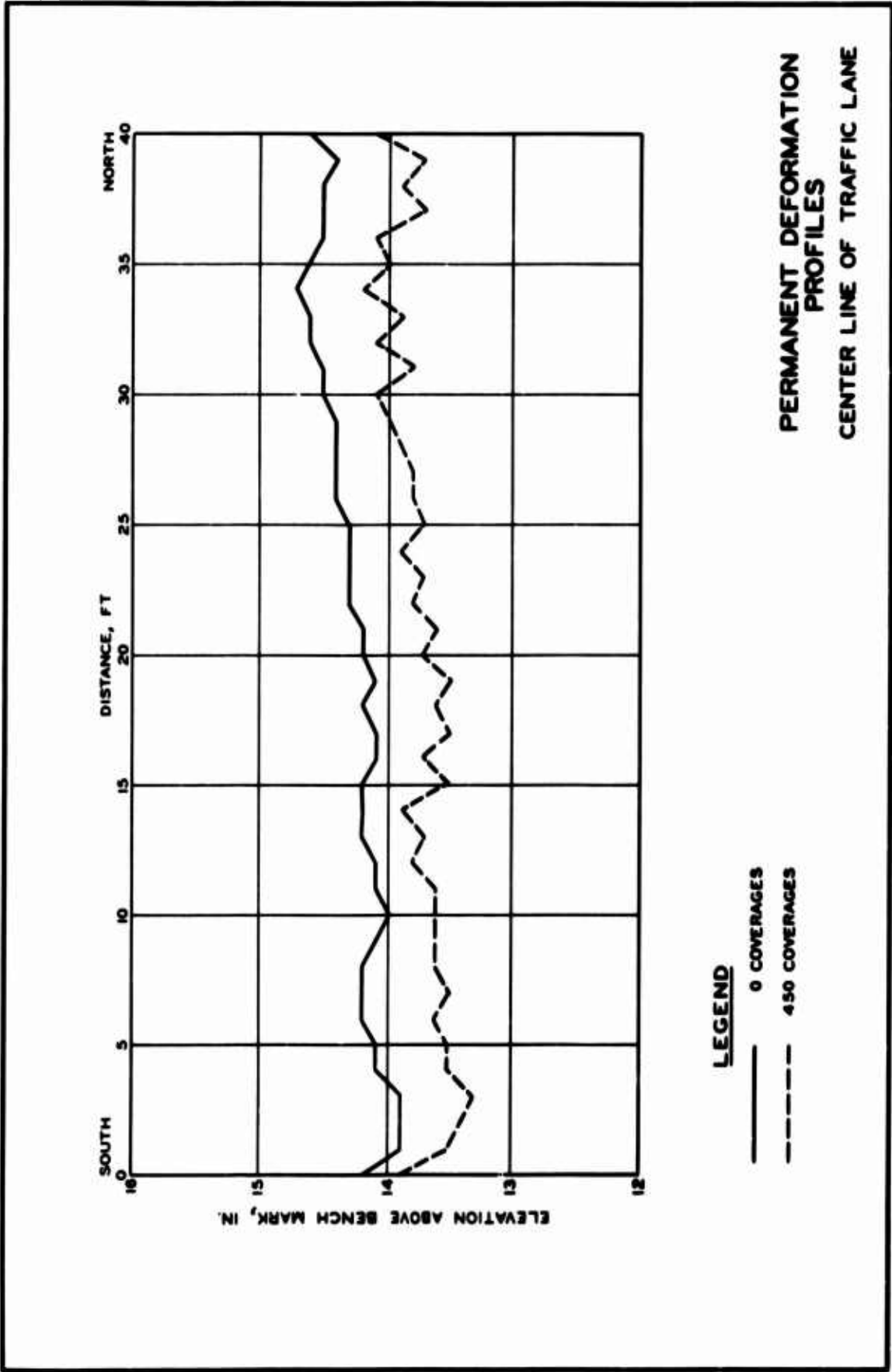
TRAFFIC DISTRIBUTION
C-130 LOADING
30,000-LB LOAD
100-PSI TIRE PRESSURE

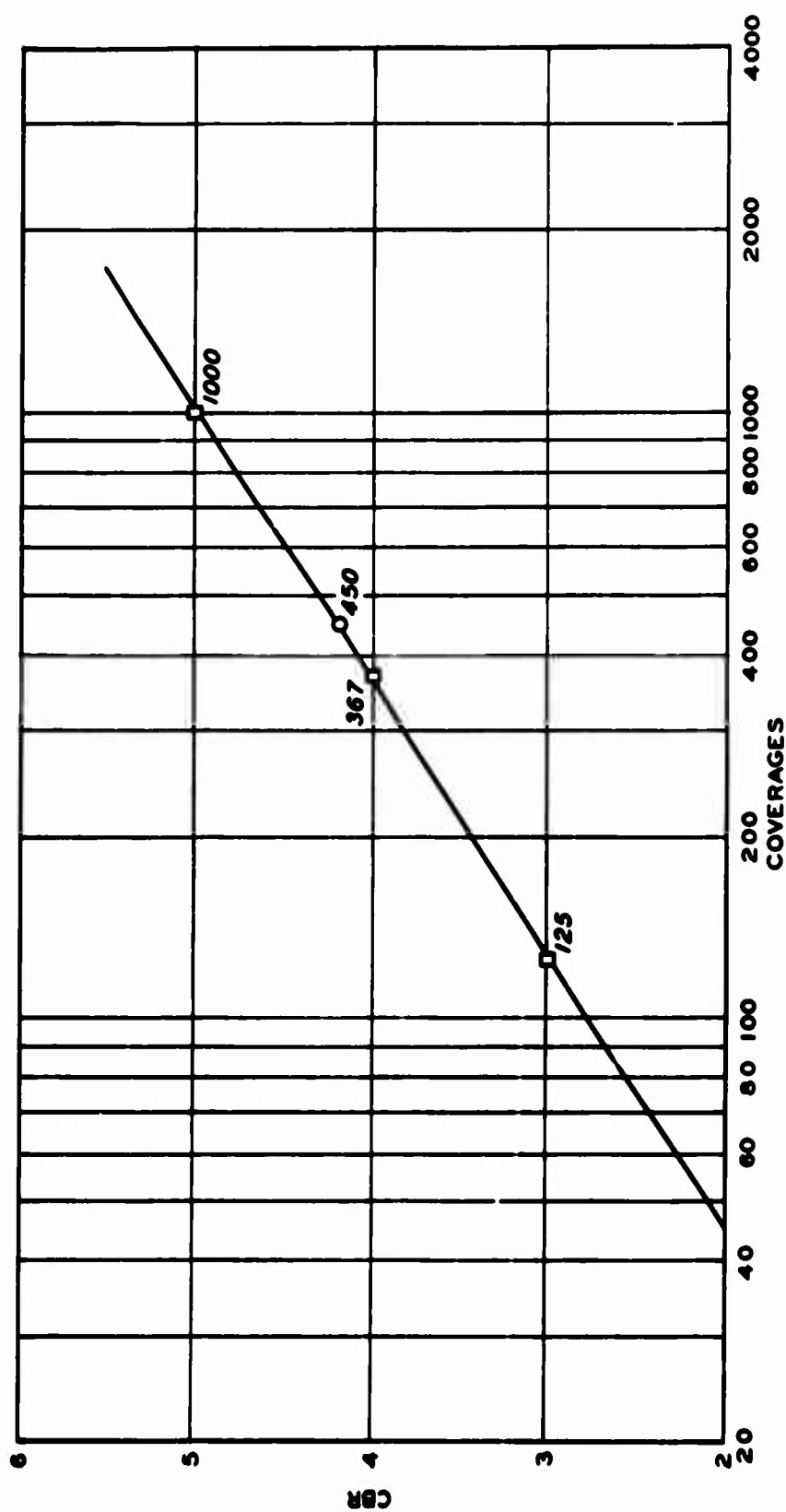




**CROSS SECTIONS
HARVEY LIGHT-DUTY MAT**

PLATE 6





LEGEND

- O SECTION FAILURE POINT
 - COMPUTED POINTS
- NOTE: BASED ON CBR EQUATION FROM REFERENCE 7.

**STRENGTH EVALUATION
OF HARVEY LIGHT-DUTY
LANDING MAT**
30,000-LB SINGLE-WHEEL LOAD
100-PSI TIRE PRESSURE

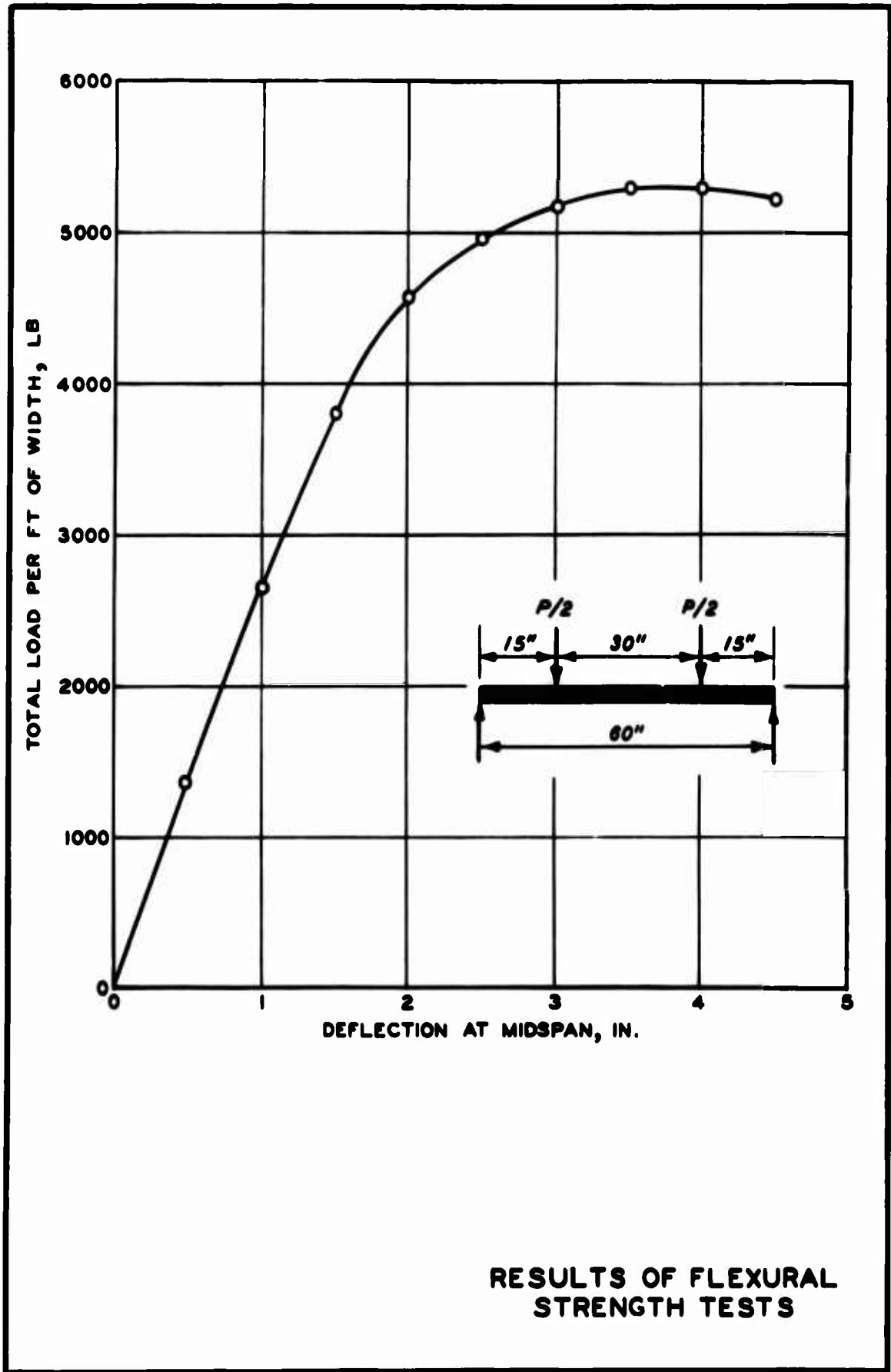


PLATE 8

APPENDIX A

REVISED DEPARTMENT OF THE ARMY APPROVED QUALITATIVE MATERIEL REQUIREMENT FOR PREFABRICATED AIRFIELD SURFACINGS

Section I - Statement of Requirement

1. Statement of Requirement

Prefabricated or expedient airfield surfacings are required to provide the Army with improved capability to produce the required aircraft landing facilities, in theaters of operations, which are essential for support of air mobility concepts. Economy in logistics and costs and flexibility in design of landing facilities can best be provided by development of mats and membranes. The landing mats will provide a bearing surface capable of supporting specified aircraft loadings on low strength soils. Use of the matting will greatly reduce the time and engineer effort required to construct airfields by substantially reducing the need for subgrade preparation and by providing a surface which can be rapidly emplaced. The membranes will provide a rapid means of waterproofing and dustproofing runways and taxiways in areas where soil strength is adequate and of waterproofing subgrades beneath landing mats. Use of the membranes will enable in-situ soil strength to be maintained, reducing airfield construction and maintenance effort required, and provide dust control, reducing safety hazards to aircraft operation and airfield detection. It is desirable that these membrane requirements be met by a single membrane. All surfacings will be lightweight, consistent with meeting operational requirements, reusable without rehabilitation if undamaged, and packaged for ease of handling. The landing mats and membranes will be of such superiority to warrant replacement of current standard items. Army engineer units or groups of indigenous personnel under Army engineer supervision will use the surfacings to improve existing airfields or to construct new airfields in all areas of the world where operations require airfield support. (TF: 70) (CDOG para 639b (2)) (Approved 14 Apr 66)

Section II - Operational, Organizational and Logistical Concepts

2. Operational Concepts

a. Requirements. The proposed airfield surfacings will provide rapid means for preparing and/or improving airfields and landing areas capable of accommodating all types of aircraft in support of military operations including strategic and tactical lift (inter-theater and intra-theater), and tactical air support. The surfaces must provide all-weather operational capability and be capable of installation during all times except when the proper subgrade conditions cannot be obtained or maintained. The landing mat must be capable of providing operational surfacing for two weeks or

500 sorties (sortie - one takeoff and one landing) without failure. A typical daily 24-hour mission for an airfield is 36 sorties. The membrane must be capable of providing operational surfacing for two weeks or 100 sorties without failure. A typical daily 24-hour mission for a membrane surfaced airfield is seven sorties. The method of construction and materials used will provide for the suppression of dust to the extent that visual detection and adverse effects on aircraft maintenance will be reduced.

b. Operational Information.

(1) Planned deployment. The proposed materiel is essential to the successful conduct of air operation within any theater of operations. The airfield surfacings may be utilized to support air operations in any land area of the world; however, primary use is expected to be in the underdeveloped areas where airfields are either nonexistent or inadequate. The surfacing will also be used to repair damage of existing airfields with like surfacings. Adoption of this materiel will provide significant reductions in logistical tonnages and manhours of installation and maintenance effort required. The proposed surfacings will be installed primarily by Army engineer combat and construction battalions or trained indigenous personnel, under supervision of Army engineers.

(2) Turnaround time. Predicted turnaround time is unknown. Turnaround time is the time needed to remove, inspect for reuse, reprovision, and install at another site.

(3) Reaction time. Reaction time is the time needed to inspect the airfield surface to determine if an aircraft can take off or land without damage. The reaction time will not exceed ten minutes per landing or takeoff. Normally, the suitability of the airfield to perform a typical 24-hour mission will be determined during a daily (1 hour essential) (30 minutes desired) visual inspection of the runway surface. The daily visual inspection will be performed from a moving ground vehicle driving up one side and down the other side of the runway with intermediate stops as necessary.

(4) Service life. The surfacing will have a service life of not less than six months or equivalent sorties with not more than a 10 percent replacement of materiel due to failures.

(5) Availability. It is desired that operational availability be at least 93 percent, with 15 percent replacement parts (AR 700-19).

(6) Reliability. The materiel shall demonstrate a Mean Time Between Failures (MTBF) of not less than two weeks or equivalent sorties. A failure is defined for the purposes of computing MTBF as a repair necessary to restore performance to within limits indicated herein and requiring greater than 24 manhours of total effort by personnel from an Engineer Platoon of the Airmobile Divisional Engineer Battalion.

(7) Durability. Surfacing materiel shall without failure complete the following initial operations requirement of 500 sorties for mat and 100 sorties for membrane.

3. Organizational and Logistical Concepts

a. The size and numbers of the installing crews will be consistent with construction requirements and the time factors dictated by operational requirements.

b. The proposed surfacings will be Class IV supply items.

c. Specific quantities required will be determined after completion of the current US Army Combat Developments Command Study, Airfield Construction Requirements, Theater of Operations 1967-1970.

Section III - Justification, Feasibility and Priority

4. Reason for the Requirement

The requirements for air support to ground combat operations have increased significantly and are continuing to grow. Present planning in both general and limited war situations, and for sustained ground, airborne and airmobile operations, call for an unprecedented volume of Air Force and Army aircraft for such air missions as inter-theater strategic lift, close tactical support, air assault operations, intra-theater airlift in an air line of communications (ALOC), and intra-division airlift to front line units. Additionally, the concept of total air mobility as developed by the Army Tactical Mobility Requirements Board will create many new aircraft missions within the front line division area. Current Army construction capabilities in support of these concepts are not compatible with requirements in terms of time and geographical areas of employment. Concepts dictate that airfields be readied in the early stages of troop deployment in airmobile operations and that airfields be located in proximity to the supported forces thereby ensuring that the mobility of the Army force is consistent with strategic and tactical objectives. Current airfield surfacing methods require either the selection of a site where the California Bearing Ratio (CBR) of the soil will sustain aircraft loadings or the extensive preparation of the subgrade to achieve necessary soil strengths. In many areas of the world where deployment of US airmobile forces is foreseen, required airfields do not exist, are too few in number, or cannot sustain the loadings of supporting aircraft. Also, construction materials for preparation of airfield subgrades and surface are not available or necessitate disproportionate demands for time and effort to locate, process, transport, emplace and compact granular materials for airfield base construction. Current military systems (PSP, M6, M8, and M9 mats) due to weight and load bearing characteristics and conventional methods of constructing airfields do not permit the development of air landing facilities for airborne and airmobile forces throughout the world on a selective basis within envisioned time parameters. Without the construction capability to

support airborne and airmobile forces their employment is seriously jeopardized if not totally prevented. This proposed system will facilitate the construction envisaged.

a. The time phasing of this requirement is immediate in relationship to present material and capabilities. The requirement satisfies immediate and long-range objectives.

b. The requirement for this type materiel is supported in CDOG paragraph 639b(2).

c. References which support this requirement are:

(1) US Army Tactical Mobility Requirements Board Final Report, August 1962.

(2) Final Report of Joint Exercise SWIFT STRIKE III, 20 November 1963.

(3) Army Air Mobile Evaluation, Headquarters, US Army Combat Developments Command, 15 February 1965.

5. Technical Feasibility

It is technically feasible, as stated Appendix I, to develop the airfield surfacings which will satisfy the requirements of this QMR.

6. Priority

This QMR is assigned Priority I, functional group 4 Tactical Movement, Appendix C, CDOG.

Section IV - Characteristics

7. Performance Characteristics

a. It is essential that the landing mats for the various classifications:

(1) Be capable of being directly installed upon graded subgrades.

(2) Be capable of withstanding the aircraft loading conditions shown on Incls 1 and 2.

(3) Be capable of withstanding coverages and loads shown on Incls 1 and 2, with a maximum of 10 percent replacement.

(4) Be capable of:

(a) Heavy duty mats will withstand aircraft operations to include maximum takeoffs using afterburner. These mats shall withstand blast effects of 700°F for 10 seconds.

(b) Medium duty mats will withstand aircraft operations to include maximum takeoffs using afterburner. These mats shall withstand blast effects of 300°F for 5 seconds.

(c) Light duty mats shall withstand C-130 aircraft assault landings utilizing maximum wheel braking and reverse thrust procedures.

(d) Surfacing at locations of arresting cables and arresting hook impacts are subject to unusual loadings and impact effects and are considered critical areas. Special surfacing will be provided when heavy and medium duty mats do not meet the requirements listed below for critical areas of runways surfaced with heavy or medium duty mats.

1. Surfacing for critical areas of heavy duty mat surfaced runways will withstand five F4 tailhook impacts of 80 knots at equivalent 18 feet per second (FPS) sink speed at the same location without structural failure due to rupture of the top surface of the mat.

2. Surfacing for critical areas of heavy duty mat surfaced runways will withstand 20 roll-over loadings on a one inch diameter arresting cable with a 50,000-lb wheel load, having a nominal tire contact area of 200 sq in. and a tire-inflation pressure of 250 psi, without structural failure due to rupture of the top surface of the mat.

3. Surfacing for critical areas of medium duty mat surfaced runways will withstand two F4 tailhook impacts of 80 knots at equivalent 18 FPS sink speed at the same location without structural failure due to rupture of the top surface of the mat.

4. Surfacing for critical areas of medium duty mat surfaced runways will withstand 20 roll-over loadings on a one inch diameter arresting cable with a 25,000-lb wheel load, having a nominal tire-contact area of 100 sq in. and tire-inflation pressure of 250 psi without structural failure due to rupture of the top surface of the mat.

(5) Be so designed so as to not cause damage to waterproofing or dust-proofing treatment applied to the subgrade, or desirably, inherently provide waterproofing and dustproofing of the underlying soil surface.

(6) Be capable of withstanding ambient temperature variations in accordance with paragraph 7c of AR 705-15, change 1, without deformation of such magnitude as to interfere with assembly and operations.

(7) Possess a surface which provides effective braking with a Runway Condition Reading (RCR) of 13-25 for aircraft landings and control during all ground operations, under conditions specified in AFR 60-13 and in paragraph 7a, b, and c of AR 705-15, change 1.

(8) Resist adverse effects, when installed operationally, resulting from exposure to POL spillage, downwash from helicopters, and wheel vehicle traffic.

(9) Be capable of storage and air transit under conditions stated in paragraph 7.1a, b, and d of AR 705-15, change 1: for closed storage, ten years; for open storage, five years without adverse effects upon the system components.

(10) Possess a service life of not less than six months or 6000 sorties with not more than a 10 percent replacement of material due to failures.

(11) Possess an operational availability of at least 93 percent, with 15 percent replacement parts (AR 700-19).

(12) Possess reliability that the Mean Time Between Failures (MTBF) shall be not less than two weeks or 500 sorties. A failure is defined for the purpose of computing MTBF as a repair necessary to restore performance to within limits indicated herein and requiring greater than 24 manhours of total effort by personnel from an Engineer Platoon of the Airmobile Divisional Engineer Battalion.

(13) Possess a durability which will enable the mats to sustain 500 sorties of initial operations without failure.

b. It is essential that the membranes:

(1) Be capable of being directly installed upon graded subgrades.

(2) Possess a surface which provides effective braking with a Runway Condition Reading (RCR) of 13-25 for aircraft landings and control during all ground operations, under conditions specified in AFR 60-13 and paragraph 7a, b, and c of AR 705-15, change 1.

(3) Be capable of withstanding wheel loads without destruction of waterproof properties when laid on soils capable of supporting these wheel loads, or when placed underneath landing mat, see Incl 3.

(4) Resist adverse effects, when installed operationally, resulting from exposure to POL spillage, helicopter downwash, and wheel vehicle traffic.

(5) Be capable of storage and air transit under conditions stated in paragraph 7.1a, b, and d of AR 705-15, change 1: for closed storage, five years; for open storage, three years without adverse effects upon the system components.

(6) Be capable of withstanding ambient temperature variations in accordance with paragraph 7c of AR 705-15, change 1, without elongation or contraction of such magnitude as to interfere with assembly and operations.

(7) Be readily repairable in the field under conditions as specified in paragraph 7a and b of AR 705-15, change 1.

(8) Possess a service life of not less than six months or 1200 sorties with not more than 10 percent replacement of material due to failure.

(9) Possess an operational availability of at least 93 percent assuming adequate logistical support.

(10) Possess reliability that the MTBF shall be not less than two weeks or 100 sorties. A failure is defined for the purposes of computing MTBF as a repair necessary to restore performance to within limits indicated herein and requiring greater than 24 manhours of total effort by personnel from a Engineer Platoon of an Airmobile Divisional Engineer Battalion.

(11) Possess a durability which will enable the membrane to sustain initial operations of 100 sorties without failure.

8. Physical Characteristics

a. It is essential that the landing mats:

(1) Be as lightweight as possible consistent with other requirements, and weigh as shown on Incls 1 and 2.

(2) Be capable of installation by trained personnel at the rates shown on Incl 1, Table 3.

(3) Permit replacement of an individual mat panel within two hours essential, one hour desirable.

(4) Be capable of placement with a minimum number of accessories and special tools.

(5) Be provided with a simple method of transition and laying from runway to taxiway and parking aprons.

(6) Be provided with an adequate system of anchoring runways and taxiways to prevent movement, lift, and not cause damage to aircraft tires.

(7) Be capable of being installed directly on graded subgrades with maximum crowns of 3 percent, longitudinal grades of 5 percent, and a maximum longitudinal grade change of 2 percent in 100 ft.

(8) Individual mats be of such size, shape, and weight to be handled by two men (desirable maximum weight - 100 lb, essential maximum weight - 120 lb).

(9) Be packaged so as to compliment ground transportation and installation and for ease of aircraft transportation in accordance with para 5a of AR 705-35.

(10) Be provided with a capability which will allow rapid replacement of buckled (forced together) and forced apart panels in the center of the runway from bomb or other damage.

(11) Be provided with components which will permit joining light duty panels to medium duty panels, and medium duty panels to heavy duty panels.

(12) (Desirable) Be provided with 45-deg transition connector panel which will allow construction of high speed taxiways.

b. It is essential that the membranes:

(1) Be as lightweight as possible as shown on Incl 1, Table 4.

(2) Be capable of being installed by trained personnel at the rates shown on Incl 1, Table 5.

(3) Withstand locked-wheel braking action and maximum wheel braking procedures of critical aircraft.

(4) Be packaged to facilitate hand laying so as to compliment ground transportation and installation and for ease of aircraft transportation in accordance with para 5a of AR 705-35.

(5) Be provided with suitable anchoring devices which will not damage the membrane or tires.

(6) Be capable of being installed directly on graded subgrades with maximum crowns of 3 percent, longitudinal grades of 5 percent, and a maximum longitudinal grade change of 2 percent in 100 ft.

9. Maintenance Characteristics

a. The mats and membranes shall be designed to minimize maintenance. It is essential that maintenance be as follows:

(1) Be designed to facilitate maintenance accessibility in the field environment at all categories so that required maintenance will be performed in the minimum practicable time with a minimum degree of skill, variety of tools, test equipment, and other supplies.

(2) Be designed towards minimization of maintenance by utilization of the most reliable components; modular construction; built-in, simple, failure indicators; and other technological advances in components and/or methods.

(3) Be designed so that individual and/or damaged sections of materials may be removed and replaced.

b. Typical maintenance to restore performance specified herein will

consist of but not necessarily be restricted to the following: cleaning, inspecting for repairs, alignment, tightening of anchors, patching, replacement of damaged mat panels, and repair of nonskid surface. Maintenance performed shall not exceed 150 manhours per month by personnel from an Engineer Platoon of the Airmobile Divisional Engineer Battalion for the service life of the materials. (Subgrade failures are not included in this paragraph.)

10. Human Engineering Characteristics

Human factors engineering characteristics of the system will include consideration of the intellectual, physical and psychomotor capabilities of the intended user.

11. Priority of Characteristics

- a. Performance
- b. Weight
- c. Reliability and Durability
- d. Transportability
- e. Maintainability

Section V - Personnel and Training Considerations

12. Quantitative and Qualitative Personnel Considerations

a. The system will be installed primarily by Army engineer units. However, its simplicity of emplacement will require a minimum of training whereby any Army unit, or indigenous personnel, could install and maintain the system.

b. No new MOS will be required.

c. Although a savings in personnel strengths normally associated with airfield construction may not be effected, with this system the troop effort required to prepare base courses can be diverted to other tasks, and the overall airfield construction time reduced.

13. Training Considerations

Training for actual installation and maintenance of this system will be negligible. Preparation of the ground for installation of this system will normally be by Army engineer units which already have this capability. Training literature on the repair and reuse of prefabricated airfield surfacing materials is required. This literature should cover the factors to be considered in evaluation of surfacing for reuse, evaluation methods and

procedures, repair techniques and methods, repackaging information, and a basis of classification of prefabricated airfield surfacing materials for future use.

Section VI - Associated Considerations

14. Training Devices

None required. Components of the system will be utilized for training.

15. Related Materiel

No change in present items of supply is anticipated. Similar items of supply already in the Army supply system may still be required to support Army aircraft operations. It is not intended that this system be capable of inter-mix usage with current standard, similar items of supply, although this would be desirable if it could be done with no compromise of capability in the proposed system. Ancillary equipment and special tools to emplace, use, and maintain prefabricated airfield surfacings must be developed as required.

16. Concealment and Deception

Normal camouflage considerations apply; reduction in light reflectivity is required. No disguise or simulation devices are required.

17. Interest

This system will probably be of interest to British, Canadian, and Australian Armies.

18. Current Inventory Items

There are no existing items, and no items are under development by other services or allied armies which can fulfill this requirement.

19. Communication Security

None.

20. Additional Comments

a. If, during the development phase, it appears to the developing agency that the characteristics listed herein require the incorporation of certain impracticable features and/or unnecessarily expensive and complicated components or devices, costly manufacturing methods or processes, critical materials or restrictive specifications which will prove excessively expensive or serve as a detriment to the military value of the unit, such matters shall be brought to the immediate attention of the Chief of Research and Development of the Army, and Headquarters, US Army Combat

Developments Command for consideration before incorporation into a final design.

b. This materiel requirement is identified by USACDC Action Control Number 7494 and supports the following:

- | | |
|--|--|
| (1) Army CD Program | Army 75 (70-75) |
| (2) Study "Engineer 75";
USACDC Action Control No. 6493 | |
| (3) Army Tasks | 1: High Intensity Conflict
2: Mid Intensity Conflict
3: Low Intensity Conflict,
Type I
4: Low Intensity Conflict,
Type II
6: Military Aid to US Civil
Authorities
7: Complementing of Allied
Land Power |
| (4) Phase | Materiel |
| (5) Function | Service Support |

3 Incl
Tables

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Table 1

<u>Mat Classification</u>	<u>Single-Wheel Load, lb</u>	<u>Tire Pressure psi</u>	<u>Nominal Contact Area sq in.</u>	<u>Coverage Level</u>	<u>CBR</u>
Heavy duty	50,000	250	200	1000	4
Medium duty	25,000	250	100	1000	4
Light duty	30,000	100	300	1000	4

Table 2

<u>Mat Classification</u>	<u>Desirable weight lb per sq ft</u>	<u>Essential Weight lb per sq ft</u>
Heavy duty	5.0	6.5
Medium duty	4.0	4.5
Light duty	2.5	3.0

Table 3

<u>Mat Classification</u>	<u>Desirable Placing Rate sq ft per man-hour</u>	<u>Essential Placing Rate sq ft per man-hour</u>
Heavy duty	400	150
Medium duty	400	250
Light duty	600	400

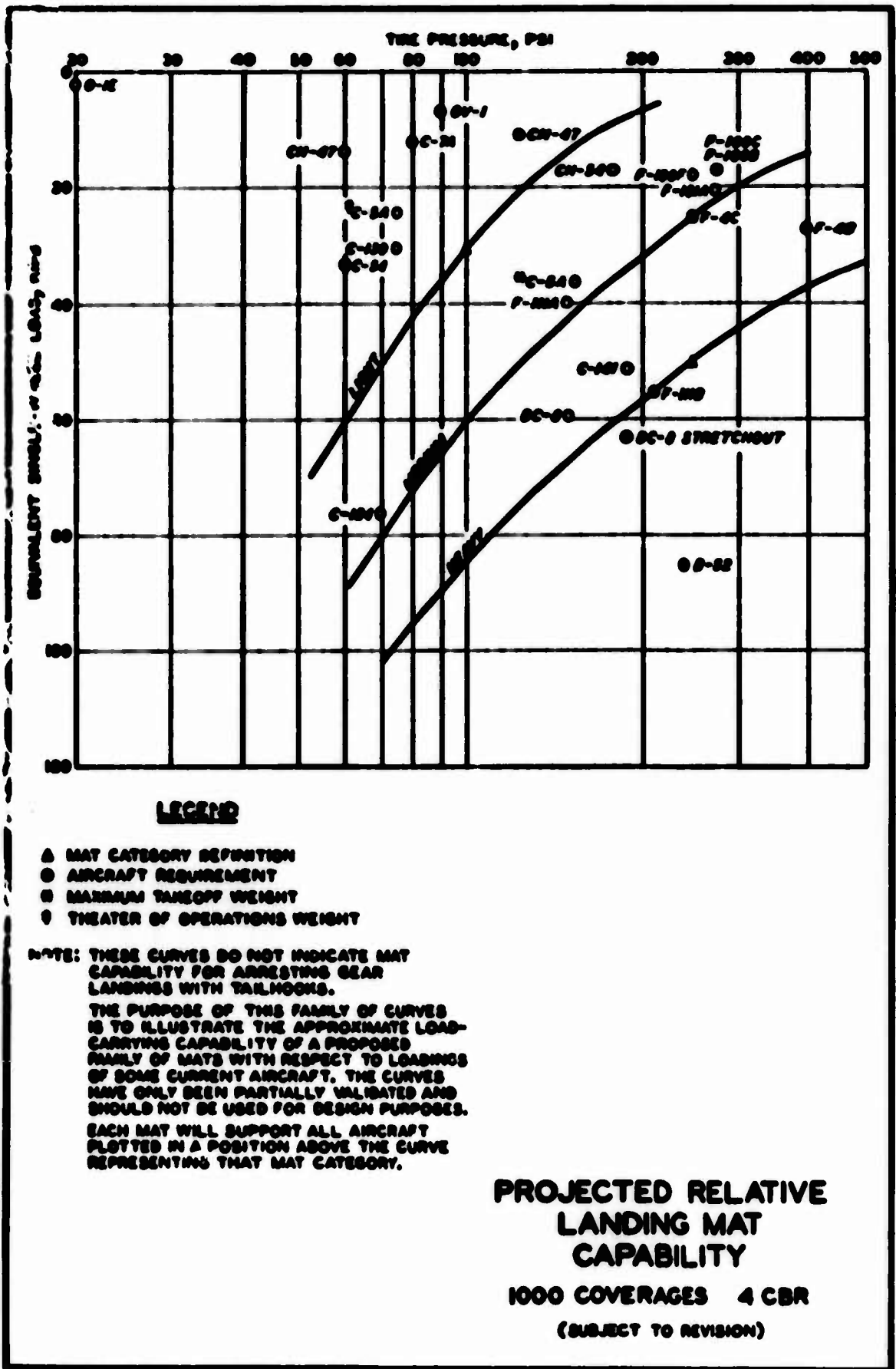
Table 4

<u>Membrane Classification</u>	<u>Desirable Weight lb per sq yd</u>	<u>Essential Weight lb per sq yd</u>
Heavy duty	5.0	6.0
Medium duty	3.0	4.0
Light duty	1.0	2.0

Table 5

<u>Membrane Classification</u>	<u>Desirable Placing Rate sq ft per man-hour</u>	<u>Essential Placing Rate sq ft per man-hour</u>
Heavy duty	300	200
Medium duty	400	300
Light duty	600	400

Incl 1 to QMR



Incl 2 to QMR

PROJECTED PERFORMANCE OF MEMBRANE FOR PERFORMING FLIGHTS (1-1-1)

(This is a preliminary table subject to revision)

Aircraft	Landing	Operation			Availability for	
		Max Engine Run-Up For	Locked Wheel Turns	Locked Wheel Braking	Waterproofing beneath	Remarks
		Takeoff			Landing Mats	
<u>Heavy-Duty Membrane (5-6 lb per sq yd)</u>						
F-111A	4	4	4	4	4	Performance on [unclear] scale for membrane: 1. Tailhook only 2. Water, the 3. Insulation of 4. No test data available.
F-111B	4	4	4	4	4	
F-4B	4	4	4	4	4	
C-141	4	4	4	4	4	
C-5	4	4	4	4	4	
C-130E	1	1	1	1	1	• Section - one landing mat and takeoff
C-7A	1	1	1	1	1	
CH-54	1	1	1	1	1	
CH-47	1	1	1	1	1	
UH-1	1	1	NA	1	NA	
OV-1	1	1	1	1	1	
O1-E	1	1	1	1	1	
<u>Medium-Duty Membrane (3-4 lb per sq yd)</u>						
F-111A	4	4	4	4	4	NOTE: The purpose of this projected performance of a family of membrane is to indicate their relative capabilities for selected current aircraft and helicopters.
F-111B	4	4	4	4	4	
F-4B	3	3	1	4	4	
C-141	4	4	4	4	4	
C-5	4	4	4	4	4	
C-130E	2	2	1	1	1	
C-7A	1	1	1	1	1	
CH-54	1	1	1	1	1	
CH-47	1	1	1	1	1	
UH-1	1	1	NA	1	NA	
OV-1	1	1	1	1	1	
O1-E	1	1	1	1	1	
<u>Light-Duty Membrane (1-2 lb per sq yd)</u>						
F-111A	4	4	4	4	4	
F-111B	4	4	4	4	4	
F-4B	4	4	3	1	3	1
C-141	4	4	4	4	4	4
C-5	4	4	4	4	4	4
C-130E	3	3	2	1	2	1
C-7A	3	3	2	1	2	1
CH-54	1	1	1	1	1	1
CH-47	1	1	1	1	1	1
UH-1	3	3	NA	3	NA	1
OV-1	3	3	3	1	1	1
O1-E	1	1	1	1	1	1